

THE
PROCEEDINGS AND TRANSACTIONS

JB
July 5/55

OF THE

Nova Scotian Institute of Science,

HALIFAX, NOVA SCOTIA.

VOLUME X.

(BEING VOLUME III OF THE SECOND SERIES.)

PART 2.

SESSION OF 1899-1900.

WITH ONE PORTRAIT AND ONE PLATE.

The First Series consisted of the Seven Volumes of the Proceedings and Transactions of the Nova Scotian Institute of Natural Science.

PRICE TO NON-MEMBERS: ONE HALF-DOLLAR.

HALIFAX /

PRINTED FOR THE INSTITUTE BY THE MCALPINE PUBLISHING CO., LTD.

Date of Publication: December 31st., 1900.

CONTENTS.

FRONTISPIECE, Portrait of the late JOHN BERNARD GILPIN, A. B., M. D., M. R. C. S., F. R. S. C.

PROCEEDINGS, SESSION OF 1899-1900:		PAGE
Presidential Address, by Alex. McKay, Esq.		xxxv
Obituary Notices of Mr. J. J. Fox, and Sir J. W. Dawson..		xxxvi
The utility of a Scientific Library and of a properly conducted Museum		xxxix
Report of the Treasurer		xli
Report of the Librarian		xlii
Ordinary Meetings		xlii
A. H. MacKay, LL. D., on the Sub-divisions of the Carboniferous System of Canada.....		xlvii
H. S. Poole, F. G. S., on the Periodical Appearance of Ants in a Chimney, and on an unusual site for a Humble-bees' nest.....		xlix
A. H. MacKay, LL. D., on Material taken from the bottom of the Atlantic by the cable steamer <i>Minia</i>		1

TRANSACTIONS, SESSION OF 1899-1900:		
I. On the Relation of the Viscosity of Mixtures of Solutions of certain Salts to their state of Ionization,—by James Barnes, B. A., Dalhousie College, Halifax, N. S.		113
II. On the Calculation of the Conductivity of Aqueous Solutions contain- ing Hydrochloric and Sulphuric Acids,—by the same.		129
III. On the Depression of the Freezing-Point by mixtures of Electro- lytes,—by the same		139
IV. On the Sub-divisions of the Carboniferous System in Eastern Canada, with special reference to the position of the Union and Riversdale Formations of Nova Scotia, referred to the Devonian System by some Canadian Geologists,—by H. M. Ami, M. A., D. Sc., F. G. S., of the Geological Survey of Canada. Ottawa,..		162
V. The Natural History of Money,—by Prof. J. Davidson, Phil. D., University of New Brunswick, Fredericton, N. B.		179
VI. On the presence of Acid Sulphate of Copper in mixtures of Aqueous Solutions of Sulphuric Acid and Copper Sulphate,—by Charles F. Lindsay, Dalhousie College, Halifax, N. S.		205
VII. On a Diagram of Freezing-point Depressions for Electrolytes,—by Prof. J. G. MacGregor, D. Sc., F. R. S., Dalhousie College, Halifax, N. S.		211
VIII. Geological Nomenclature in Nova Scotia,—by Hugh Fletcher, B. A., of the Geological Survey of Canada		235
IX. Notes on a Cape Breton mineral containing Tungsten, and on the effect of washing certain Cape Breton coals,—by Henry S. Poole, F. G. S., F. R. S. C., Assoc. Roy. Sch. Mines, etc., Stellar- ton, N. S.		245
X. Minerals for the Paris Exhibition,—by E. Gilpin, Jr., LL. D., F. R. S. C., Inspector of Mines		248
XI. On the Variation of the Rigidity of Vulcanized India-Rubber with Tension,—by Thomas C. Hebb, B. A., Dalhousie College, Hal- ifax, N. S.		273
XII. Records of Post-Triassic Changes in Kings County, N. S.,—by Prof. E. Haycock, Acadia College, Wolfville, N. S.		287
XIII. Phenological Observations. Canada, 1899,—by A. H. MacKay, LL. D., Halifax, N. S.		303
XIV. A Fresh-water Sponge from Sable Island,—by the same.		319

APPENDIX II:

List of Members, 1899-1900	V
----------------------------------	---

Please acknowledge receipt (though not necessarily on this form,) to THE NOVA SCOTIAN INSTITUTE OF SCIENCE,
Halifax, Nova Scotia, Canada.

*Received from the Nova Scotian Institute of Science,
Part 2 of Volume X (being Volume III of the Second Series) of its "Proceedings and
Transactions."*

Signature or Stamp of
Recipient.

If package was not properly addressed, address to be given here.

Handwritten text, possibly a signature or name.

Handwritten text, possibly a date or location.

Vertical text on the left margin, possibly a page number or reference.

MEMBERS of the Institute, and Societies in correspondence with it, would confer a great favor, if they would send to the Council, for distribution to Scientific Institutions whose sets of the Institute's publications are incomplete, any duplicate or other spare copies which they may possess of back numbers of its Proceedings and Transactions. They should be addressed : *The Secretary of the N. S. Institnte of Science, Halifax, Nova Scotia.*

THE attention of members of the Institute is directed to the following recommendations of the British Association Committee on Zoological Bibliography and Publications :—

“That authors' separate copies should not be distributed privately before the paper has been published in the regular manner.

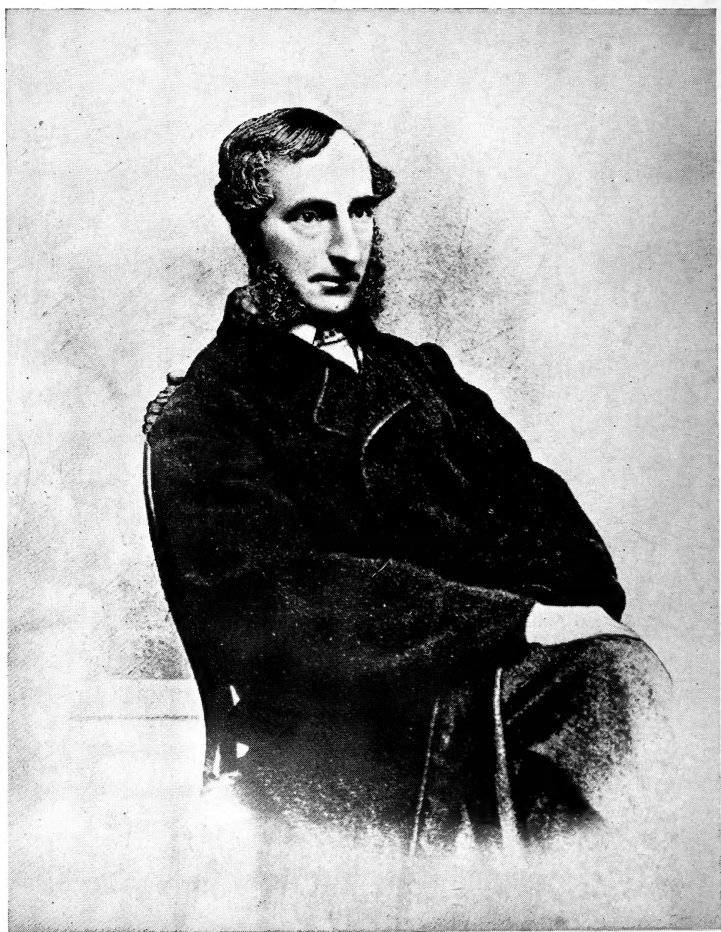
“That it is desirable to express the subject of one's paper in its title, while keeping the title as concise as possible.

“That new species should be properly diagnosed and figured when possible.

“That new names should not be proposed in irrelevant footnotes, or anonymous paragraphs.

“That references to previous publications should be made fully and correctly, if possible in accordance with one of the recognized sets of rules of quotation, such as that recently adopted by the French Zoological Society.”





W. B. G. Gilpin

PROCEEDINGS

OF THE

Nova Scotian Institute of Science.

SESSION OF 1899-1900.

ANNUAL BUSINESS MEETING.

Legislative Council Chamber, Halifax, 20th November, 1899.

The PRESIDENT, ALEXANDER MCKAY, Esq., in the chair.

The PRESIDENT addressed the Institute, as follows :—

GENTLEMEN,—A review of the last year's work of this Institute may well be very brief. Meetings were held at the usual times, except in February, on account of a severe storm. Twelve papers were read and discussed, and another was read by title. These cover a wide range of subjects: Social science, geology, sanitary science, mineralogy, medicine, chemistry and botany, zoology and physics.

Prof. Davidson, of the University of New Brunswick, opens up a field new to the Institute by a valuable paper "On Statistics and Expenditure in Canada." In this and related studies there are splendid opportunities for unlimited research and the display of the highest order of talents. A paper by Prof. Russell on "School Room Air" will be of much interest and value to teachers. The tests recommended are inexpensive, and such as can be generally used. Teachers who have once made these tests will ever afterwards be more alive to the almost criminal carelessness of those who allow children to occupy badly-ventilated school rooms. Dr. A. P. Reid also deserves the

thanks of the Institute for calling attention to the spread of consumption by contagion and its prevention by means of properly constructed sanatoria, of which he exhibited a model. In the phenological observations of the school children, collected by Dr. MacKay, and in the experiments in physics and chemistry conducted by Messrs. Barnes and Lindsay—promising young students of Dalhousie College—we see hopeful signs of a reviving interest for science in Nova Scotia. Mr. Piers has favored us with “No. 5 of Notes on Nova Scotia Zoology.” Dr. Mackay, who is our only authority on the Diatomaceæ of Nova Scotia, has awakened a fresh interest in one of his favorite studies by another paper reporting progress, and by exhibiting excellent microscopic slides of our principal diatoms.

Upon the whole, then, the work of the year has been of very considerable interest and of some scientific importance.

We have added to our numbers two ordinary members, one corresponding member and three associate members. We record with sorrow the death in September of one of our oldest and most faithful members, Mr. J. J. Fox. He was born in Salisbury, England, in 1818. He studied medicine, but preferred a seafaring life, and spent many years full of adventure in Egypt, Greece, the West Indies and South America. In 1852 he was appointed by the Imperial Government comptroller of customs and navigation laws at Magdalen Islands.

A faithful performance of duties soon led to advancement, and for many years he was familiarly known as “governor.” He was characterized by modesty, bravery and humanity. For valuable services to shipwrecked mariners he was presented by the President of the United States with a magnificent gold watch valued at \$1,000. His intimate knowledge of the fisheries made him a most valuable witness before the Halifax fishery commission in 1877. After retiring from the civil service he lived in Halifax, joined the Institute, and seldom missed a meeting.

To-day brings us sad tidings of the death yesterday of Sir William Dawson, the most distinguished member of our Institute and the most eminent scientific man in Canada. He was born in Pictou in 1820. At a very early age he began his studies in natural history, thereby cultivating his powers of observation, and thus laying the foundation for his remarkable achievements in geology subsequently. His success in this respect is a good argument in favor of the early introduction into our course of study of science teaching.

Mr. Dawson graduated from Edinburgh University at the age of 26. For four years he studied geology, travelling part of the time with Sir Charles Lyell, the greatest geologist of the world. At the age of thirty he was superintendent of schools for Nova Scotia, and did much to lay the foundation of our present educational system. In 1855 he was appointed Principal of McGill University, a position which he held until 1893, until he and the University had become famous the world over.

He was capable of a prodigious amount of hard work. In his favorite science he kept in the foremost rank, but he found it difficult to avail himself of the light thrown upon natural phenomena by the theory of evolution of which he was a most uncompromising opponent.

His extraordinary industry is shown by the large number of books and scientific articles which he wrote. Some of them were of very great value and are still used as text books.

His eminent services to science were acknowledged by his appointment as first President of the Royal Society of Canada in 1882, his election in the same year as President of the American Geological Association, and of the British Association in 1886. He received honorary degrees from various universities, and was knighted in 1884.

At the close of my address last year I referred to the fact that science was much neglected or very badly taught in our schools. As a remedy I suggested (a) that the colleges prescribe science as a subject for matriculation, (b) that for the academic license more scholarship, especially in practical science, and a long course of the best professional training be made imperative, (c) that higher qualifications in science be required for B licenses, and (d) that a large part of the provincial examination in science for grade A consist of laboratory work.

The progress of science teaching in other countries during the last year has all been in confirmation of the soundness of these principles. No doubt the time is near when we also must adopt them. When that day comes, and not until then, science will make satisfactory progress in all our educational institutions.

But it is perhaps more especially the province of this Institute to awaken the public to an interest in general science and to stimulate and assist individuals in particular fields of research.

In reference to this aim I may be allowed to make some additional suggestions :

1. We should have a scientific library easily accessible to scientific workers in every part of the Province. At present we have nothing of the kind. A collection of partially catalogued, somewhat inaccessible reports of scientific societies cannot be said to be such a scientific library as the majority of workers need, however useful it may be to those engaged in original research.

We require not less than 5,000 volumes of the latest books by the ablest men of science ; 10,000 would be better. In addition to this there should be complete sets of all the scientific periodicals in English, French and German.

Such a collection of standard science textbooks, supplemented by government reports on agriculture, forestry, fisheries, etc., and the reports of scientific societies, and managed by a competent librarian, would be of incalculable benefit. I have no hesitation in saying that I believe it is the duty of our government in its encouragement of technical instruction to establish such a library. If there existed an intelligent appreciation of its value the cost would not long be a hindrance, for the number of books required would not be large, and probably many of them would be received as donations.

But why should the government provide a science library any more than a law library or a historical library ? Because science in some form or other lies at the foundation of success in all the industries of the country, so that the government would be justified and supported in making an expenditure which would result in such general benefit. Facilities for scientific research would lead to discoveries which would pay the cost a thousand fold. Pasteur's discoveries were worth untold millions to France.

Although Nova Scotia is not large, populous or rich, yet her natural resources are so great and varied as to warrant the government in following the examples of other countries in respect to technical education; and the establishment of a good science library would be but the first and most natural step in that direction.

Recently I wanted to consult twenty or thirty scientific works and periodicals. In the three largest public or quasi-public libraries of Halifax I was able to find but one of them. No wonder that our ablest young men are lost to the Province when we deny them the opportunities for research which they readily obtain elsewhere.

Here let me call your attention to the most valuable and self-sacrificing labors of Dr. MacGregor and Mr. Maynard Bowman in connection with the library of this Institute. A few years ago, when they began work upon it, it consisted of a small number of unclassified reports from societies in various parts of the world. It now includes a large number of serial publications by scientific societies and other institutions, and numbers about 1,500 bound volumes with about as many more unbound. These have been placed in a room temporarily provided by Dalhousie College, and so arranged that any one desirous of consulting any volume would be able to find it without the assistance of the librarian.

The work of bringing order out of the confusion that existed at first, the cataloguing and labelling of so many books, searching and sending abroad for missing numbers, was an immense labor, which if performed by a paid expert would have cost several hundred, not less, perhaps, than two thousand dollars.

But in addition to all this, the addresses of other societies had to be searched and copies of our Transactions sent abroad to about 700 societies in all, by which means the number of valuable publications received each year was more than doubled. Surely when these two gentlemen have done so much, we may expect our provincial government to supplement their efforts by the addition to this library each year of a few hundred treatises. Then would it not be better that the library thus enlarged should be taken over by the government, properly housed and managed, and made free to the public?

Nor must I forget to say that the thanks of this Institute are due to the Governors of Dalhousie College for the use of a room at a time when our library became so large that it could no longer be kept in the place which it formerly occupied.

2. A properly conducted museum would do much to popularize science in our midst. A collection of dusty, unlabelled, badly arranged specimens does not amount to much and scarcely justifies the expense. Such a museum is the deadest of all dead things.

To be practically useful a museum requires a large, well-lighted, readily accessible room. It should primarily contain typical specimens of the most important natural bodies, arranged according to their chemical or organic affinities, so that the student may learn from them at a glance something of their relationship and the laws of nature

Especial attention should be given to the products of this Province. They should be scientifically marshalled and their industrial applications carefully and suggestively illustrated. Raw products in every stage of their manufacturing processes should be exhibited.

The museum should be in charge of a man of the broadest scientific culture, a man of business capacity, and a thorough teacher.

A museum thus equipped would do more for science than any college or any other agency. Every visitor from the country would return to his home with his curiosity awakened, and often with scientific problems or difficulties solved, with a new inspiration for further advances.

Such an institution would have organic connection with every high school and college in the province, exchanging specimens and thus enriching the local school museums, diffusing scientific information, and stimulating scientific activity.

How often throughout the last sixteen years have our teachers lamented the want of opportunity in this respect? During their holidays they would have made large collections of interesting objects which they would study in classes formed at the museum. Long since every school in the city, after the example of the German schools, would have been supplied with a respectable collection of labelled specimens for the instruction of their pupils, and the amount of scientific knowledge and interest would have been increased tenfold.

For the sake of economy and efficiency the museum and the science library should be in the same building and in charge of the curator of the museum.

Book and specimen are complementary and should be drawn as close together as possible. "First of all, their aims are identical, for they have the one end in view, the culture of the people; secondly, they appeal to the same mental faculties with which all men are endowed in a greater or less degree, and thirdly, to a very great extent one of them, the museum, to carry out its proper functions to a great measure, is dependent on the other. It leans upon it, as it were; it looks to it to minister to the museum visitors that information which the most comprehensive catalogue and labels in the world would fail to supply."*

If all the specimens were labelled giving references to the books in which they were best described, placed on a shelf near at hand, the

* C. W. Wallis, Curator Birmingham Art Galleries and Museum.

student's ability to do better work and the extent to which both library and museum could be utilized would be greatly increased. The tendency in England, Ontario and the United States is towards combining libraries and museums in the same building.

In conclusion, when the colleges come to see that good work in science in the high school gives, to say the least, as valuable mental discipline as classics, and vastly more of useful knowledge; when the education department provides adequate professional training for the higher teachers, and subjects them to tests in the laboratory which will demonstrate their fitness for teaching science, and when the government will supply us with a well-equipped museum and science library in one building, then but not before we will make satisfactory progress in science.

The thanks of the Institute were presented to MR. MCKAY for his services as President.

The TREASURER'S report was presented, and having been audited and found correct, was received and adopted. The following is an analytical statement of the expenditure for 1898-99 :—

PUBLICATION OF TRANSACTIONS:—

Vol. IX, Part 4 (1897-98):

Printing and binding	\$171 40	
Less received for authors' separates and two copies sold	8 00	
	—	\$163 40
Vol. IX, Parts 1-4. Preparation of Index		2 00

Vol. X, Part 1:

Printing	\$ 8 00	
Photographs for Portrait	1 00	
Engravings	14 13	
Expressage	75	
	—	23 88

Vol. X, Part 2, 3 or 4:

Photograph for Portrait.....	25	
	—	\$189 53

DISTRIBUTION OF TRANSACTIONS:—

Vol. IX, Part 4:

Wrappers, receipts, wrapping, twine.....	\$14 50	
Addressing	15 00	
Postage, truckage, freight, expressage, insurance.....	15 39	
	—	44 89
<i>Carried forward</i>		\$234 42

Brought forward \$234 42

LIBRARY EXPENSES :—

Insurance (including stock of Transactions)....	\$16 88	
Janitor, Dalhousie College, for services	5 00	
Asst.-Librarian, Dalhousie College, for services	10 00	
Librarian, clerical expenses.....	25 00	
Fittings	12 77	
Arranging Library, preparing card catalogue, etc.....	75 00	
Truckage.....	3 80	
Binding.....	95 65	
Freight and postage on back numbers of Transactions sent in exchange.....	4 01	
Petty expenses.....	2 55	
		<hr/>
Calling of meetings.....		250 66
Advertising.....		28 00
Postage (Secretaries and Librarian).....		6 00
P. O. Box.....		11 85
Miscellaneous printing (including stationery).....		4 00
Type-writing.....		2 50
		<hr/>
		50
		<hr/>
		\$537 93

The Report on the Library was presented by the Librarian and Corresponding Secretary.

During the year the Transactions had been sent for the first time to the following :—

*Königl. Landesarchiv, Agram, Austria-Hungary.

Elektrotechnischer Verein, Berlin, Germany.

Real Academia de Ciencias Naturales y Artes, Barcelona, Spain.

Naturæ Novitates, Berlin.

*Musée du Congo, Brussels.

Baltimore Astronomical Society, Baltimore, Md.

*Maryland Geological Survey, Baltimore, Md.

Library, Harvard University, Cambridge, Mass.

New Hampshire State Library, Concord, N. H.

*Natural History Association of Miramichi, Chatham, N. B.

*K. Vetenskaps- och Vitterhetssamhället, Göteborg, Sweden.

Real Academia de Ciencias Medicas, Fisicas y Naturales; Habana, Cuba.

Periodico di Matematica, Leghorn, Italy.

Lincolnshire Science Society, Lincoln, G. B.
 Public Library, Museum and National Gallery, Melbourne.
 *Canadian Mining Institute, Montreal.
 Club Alpin de Crimée, Odessa, Russia.
 Rivista di Patologia Vegetale, Portici, Italy.
 Pasadena Academy of Science, Pasadena, Cal.
 *Philadelphia Commercial Museum, Philadelphia, Pa.
 Rochdale Literary and Scientific Society, Rochdale, G. B.
 *Augustana College, Rock Island, Ill.
 "Minerva," Strassburg, Germany.
 *Institut de Botanique, R. Université des Etudes, Sienne, Italy.
 State Laboratory of Natural History, Urbana, Ill.
 Concilium Bibliographicum, Zurich-Neumünster, Switzerland.
 American Microscopical Journal, Washington, D. C.

Publications have been received for the first time from the institutions indicated by an asterisk in the above list, and from the following:

Observatorio de Manila, Manila.
 Education Department, Wellington, New Zealand.
 Public Museum, Wanganui, New Zealand.
 Birmingham and Midland Institute, Birmingham.
 "La Science Sociale," Paris.
 Treasury Department, Washington, D. C.
 South Staffordshire Institute of Iron and Steel Works Managers,
 Dudley, G. B.
 Radcliffe Observatory, Oxford, G. B.
 K. Ungarische Geographische Gesellschaft, Vienna.
 Société Anversoise pour la Protection des Animaux, Antwerp.
 Society of Civil Engineers, Boston.
 Halifax Scientific Society, Halifax, Eng.
 Université Imperiale de Moscou, Russia.
 Carnegie Museum, Pittsburg, U. S. A.
 K. Botanische Gesellschaft, Regensburg.
 Kansas State Agricultural College, Manhattan, Ka.
 Public Library, New York.
 Société Linnéenne de Lyon, Lyons, France.
 Academie des Sciences, Belles Lettres et Arts, Lyons, France.
 Royal Society of Victoria, Melbourne.
 Academy of Science, Washington, D. C.

New England Zoological Club, Cambridge, Mass.

Public Library, Museum and Art Gallery, Adelaide, So. Australia.

Engineering Association of New South Wales, Sydney.

Associazione Mathesis, Leghorn, Italy.

Wisconsin Geological and Natural History Survey, Madison, Wis.

Société Nationale des Antiquaires de France, Paris.

Lloyd Mycological Museum, Cincinnati.

The Transactions were now being sent annually to 779 institutions of various kinds, and exchanges had been received from 447.

The distribution of the Transactions to Corresponding Societies and other institutions in all parts of the world had again, through the courtesy of the Secretary of the Smithsonian Institution, Washington, been effected at small expense, through the Institution's Bureau of International Exchanges. The total expense of distribution had been \$44.89, which included printing of wrappers and receipt forms, wrapping and addressing as well as postage (on Canadian packages), and freight.

At the date of the last report 113 volumes were in the binder's hands. Subsequently 89 volumes were added to these; and these 202 volumes are now on the shelves. The total cost of binding them was \$170.65, but as \$75.00 was provided for last year, only the balance of \$95.65 appears in this year's account. The books bound were mostly English, but some foreign publications which were in demand by members were included. The number of bound volumes in the Library is now 1,482; and there must be a somewhat larger number of unbound volumes, though we have never made a count of the unbound volumes.

The recommendation made last year that a paid assistant should be provided to get the library into a condition in which it would be of greater use to the members, was carried out during the past year, the services of Miss N. K. MacKay, who had previously been Asst.-Librarian of Dalhousie College, having been secured for some weeks during the summer.

The following work was accordingly carried out:—

(1) The arranging of books on the shelves and the labelling of shelves referred to in last report, had been completed. It is thus possible for members to find any books they may desire without difficulty, even in the absence of the Librarian.

(2) All unbound volumes, in parts, were examined and tied up, note being made of their defects. This had previously been done in the case

of most of the English books. It has now been done for the whole library.

(3) Memoranda were made out for transmission to corresponding societies, of the parts lacking in our sets of their publications.

(4) A card catalogue of the whole library was prepared according to the method in use in the Library of the Academy of Arts and Science of Philadelphia. The catalogue in the case of serial publications specifies of course only the volumes of the various series which are on the shelves, without giving any clue to their contents. In the case of publications which, though issued by one institution, do not form a numbered series, each volume or report is separately catalogued. The catalogue consists of about 1200 cards.

While the whole of the work, carried out in an admirable manner by Miss MacKay, forms a necessary preliminary to the issue of a printed catalogue for the use of our members, we are not yet ready to issue such a catalogue, at least to issue one which would be permanently useful. For many of the unbound volumes in the library are defective, and it would be well to get these defects supplied as far as may be possible before printing. The Corresponding Secretary hopes during the present year to transmit the memoranda of defects referred to above to the various corresponding institutions, and to make some progress in getting the defects supplied.

The report was adopted, and the thanks of the Institute tendered to Mr. Bowman and Dr. MacGregor for their work in connection with the library.

On motion of DR. MACKAY, it was resolved that the Council be directed to prepare a resolution appreciative of the scientific career of the late Sir William Dawson and regretting his recent death.

It was resolved that the Council be instructed to approach the Government for the purpose of ascertaining if it would be possible for the latter to provide space, in the new Government building, for the accommodation of the Institute's library.

The thanks of the Institute were presented to the HON. ROBERT BOAK, President of the Legislative Council, for granting the use of the Council Chamber, and to the SECRETARY OF THE SMITHSONIAN INSTITUTION for his courtesy in continuing to admit the Institute to the privileges of the Bureau of International Exchanges.

The following were elected officers for the ensuing year (1899-1900):

President.—A. H. MACKAY, ESQ., LL. D., F. R. S. C., *ex officio* F. R., M. S.

Vice-Presidents.—F. W. W. DOANE, ESQ., C. E., and HENRY S. POOLE, ESQ., F. G. S.

Treasurer.—WILLIAM C. SILVER, ESQ.

Corresponding Secretary.—PROF. J. G. MACGREGOR, D. SC.

Recording Secretary.—HARRY PIERS, ESQ.

Librarian.—MAYNARD BOWMAN, ESQ., B. A.

Councillors without Office.—ALEXANDER MCKAY, ESQ.; EDWIN GILPIN, JR., ESQ., LL. D., F. R. S. C.; MARTIN MURPHY, ESQ., D. SC.; WILLIAM MCKERRON, ESQ.; PROF. EBENEZER MACKAY, PH. D.; WATSON L. BISHOP, ESQ.; RODERICK MCCOLL, ESQ., C. E.

Auditors.—HERBERT E. GATES, ESQ., and G. W. T. IRVING, ESQ.

FIRST ORDINARY MEETING.

Legislative Council Chamber, Halifax, 20th November, 1899.

The PRESIDENT, DR. MACKAY, in the chair.

The meeting was held after the adjournment of the Annual Business Meeting.

DR. H. M. AMI communicated a paper "On the Subdivisions of the Carboniferous System in Eastern Canada," but owing to the lateness of the hour the reading of the paper was deferred.

SECOND ORDINARY MEETING.

Legislative Council Chamber, Halifax, 11th December, 1899.

The PRESIDENT in the chair.

The council reported that ERNEST HAYCOCK, ESQ., Instructor in Chemistry, Mineralogy and Geology, Acadia College, Wolfville, N. S., had been elected an Associate member.

The following resolution was adopted :—"This Institute has learned with the greatest regret of the death of its distinguished Corresponding Member, SIR J. W. DAWSON, and desire to place on record its profound sense of the eminence of the services rendered by him to the cause both of Science and of Education, during a long life, which was happily as fully characterized by successful results, as by unremitting efforts towards the attainment of a noble ideal.

"The Institute desires to convey to LADY DAWSON and her family, an expression of the deep sympathy with which its members have heard of the sad bereavement she and her family have experienced."

A paper by HENRY M. AMI, Esq., D. Sc., of the Geological Survey of Canada, "On the Sub-divisions of the Carboniferous System in Eastern Canada," was read by DR. E. GILPIN who gave an introductory statement of a popular character. (See Transactions, p. 162).

The subject was discussed by DR. GILPIN, MR. J. FORBES and others.

The president, DR. A. H. MACKAY, said he was glad to have DR. AMI's views presented to the Institute. He spent a fortnight with Mr. Fletcher in running over the stream-exposed sections of the southern flanks of the Cobequids; and became deeply interested in some of the problems discussed in the paper. The extremely careful work done of late years had thrown new light on the problems attempted to be solved by the older geologists from their original but more limited observations. Mr. Fletcher has reason to feel gratified that Dr. Ami and Dr. Dawson admit that his maps of the region in question "show clearly the true and natural order of sequence of the formations;" so that the reference to "types that are everywhere held to be of carboniferous age" must indicate a revision of the older geological nomenclature of some regions. Sir William Dawson, a most eminent palæontologist as well as geologist, after studying the fossil plants and animals of Riversdale, MacKay Head, and Harrington River, placed them in the Millstone Grit formation as intimately related to those of the Coal Measures. Dr. Ami now correlates them with the Lancaster fern ledges (hitherto known as Devonian) of New Brunswick; but he would place them all in his new Eo-carboniferous. Of the twenty-one fossil species enumerated by Dr. Ami, fifteen were Dawson's own species. *Psilophyton glabrum* belonged to a genus hitherto generally considered to be characteristic of the Devonian. *Leaia Leidyi* (perhaps identical with *Leaia tricarinata*) was found in rocks called Devonian by many geologists. *Belinurus grandævus* and *Estheria Dawsoni* represented genera usually considered common both to the Devonian and the Carboniferous, with specific names given to specimens obtained from the rocks in dispute. Dr. Ami's new species *Sauropus Dawsoni* was stated to be only "apparently from rocks of this age." Mr. Fletcher would appear to oppose the assumption that the rocks underlying the New Glasgow conglomerate

are equivalent to the coal measures of Stellan, according to his views given in the Report of the Geological Survey for 1886, which he did not appear to have since changed.

These differences of opinion demonstrated that new information was being acquired, and was in the course of being assimilated by the geologists. But whether taking the upper slice from off our old slenderly developed Devonian and attaching it with its unconformity to the base of our corpulent Carboniferous is the true rectification of the old nomenclature, remained, perhaps yet to be indubitably determined. If the true order of superposition of rocks can be ascertained at any point from the observation of their actual bedding, the palæontologist must modify his hypotheses based on defective biological horizons observed elsewhere, so as to harmonize with the facts of the stratigraphist. It was the stratigraphist in the first place who determined the biological horizons for the palæontologist. But the palæontologist with his biological horizon becomes the supreme arbitrator where the stratigraphist is not sure of his base, or of the order of superposition.

PROF. J. G. MACGREGOR, communicated a paper, "On Laws of Dilution for Aqueous Solutions of Electrolytes."

THIRD ORDINARY MEETING.

Legislative Council Chamber, Halifax 15th January, 1900.

The PRESIDENT in the chair.

A communication was read from the EIGHTH INTERNATIONAL CONGRESS OF NAVIGATION, inviting the Institute to appoint a delegate to attend the meeting of the Congress to be held at Paris in July next. The matter was referred to the Council for action.

JAMES BARNES, ESQ., B. A., Dalhousie College, presented two papers:—

1. "On the Relation of the Viscosity of Mixtures of Solutions of Certain Salts to their State of Ionization." (See Transactions, p. 113).
2. "On the Calculation of the Conductivity of Aqueous Solutions containing Hydrochloric and Sulphuric Acids." (See Transactions, p. 129.)

A vote of thanks was presented to MR. BARNES for his communications.

FOURTH ORDINARY MEETING.

City Council Chamber, Halifax, 12th February, 1900.

The PRESIDENT in the chair.

A paper entitled : " Nova Scotian Minerals collected for the Paris Exhibition," was presented by EDWIN GILPIN, JR., ESQ., LL. D., F. R. S. C., Inspector of Mines. DR. GILPIN answered a number of inquiries made by those present, relative to the minerals of the Province. (See Transactions, p. 248.)

A communication by HENRY S. POOLE, ESQ., F. G. S., entitled " Notes on the Periodical Appearance of Ants in a Chimney, and on an Unusual Site for a Humble-Bee's Nest," was read by the RECORDING SECRETARY in the absence of the author, as follows :

" For many years, possibly fifteen, a flight of ants has annually tumbled down a chimney in the office of the Acadia Coal Co., at Stellarton, N. S., generally on August 24th, sometimes a day or two later, and occasionally a few ants again appear as late as the middle of September. Fires are used in the chimney each winter. A tinned roof has been put on the office since the ants first were seen, and the top of the chimney has been thoroughly repaired by masons without finding a nest. The habitat selected seems unusual, and so far has not led to the similar adoption by colonies of other chimneys in the same building.

" In a grove of young fir trees, about eight feet from the ground, I noticed one autumn a large robin's nest in unusually good repair. On pulling down the tree-top the nest was found to be full, with a dome shaped cone. It was occupied by humble-bees and a small comb with larvæ in it. Such a situation for a humble-bees' nest, I am told, has been seen before, but apparently it is unusual."

FIFTH ORDINARY MEETING.

City Council Chamber, Halifax, 12th March, 1900.

The PRESIDENT in the chair.

It was announced that CHARLES PICKFORD, ESQ., had been elected a Corresponding Member.

A paper by C. M. PASEA, ESQ., of Dalhousie College, " On a relation between the Ionization Coefficients of Electrolytes, and its application as an Interpolation Formula," was presented by DR. J. G. MACGREGOR.

JAMES BARNES, Esq., B. A., Dalhousie College, read a paper "On the Depression of the Freezing-point by Mixtures of Electrolytes." (See Transactions, p. 139.)

The paper was discussed by Drs. MACGREGOR and MACKAY, and a vote of thanks was presented to the author.

DR. A. H. MACKAY, exhibited, with comments, material taken from the bottom of the Atlantic at four different points, by the Cable S. S. *Minia* in charge of Captain De Carteret, by whom the specimens were presented.

1. From lat. $40^{\circ} 47' N.$, long. $38^{\circ} 45' W.$, at a depth of 2544 fathoms, in June, 1899 :—

a. A fragment of a dark igneous rock about $13 \times 8 \times 5 \text{ cm}$, not very unlike some massive, dark green traps of Nova Scotia. The Cable was hooked at the same time, but broke and slipped over the stone which was abraded in two separate places. The exact determination of the rock, as well as the other specimens, had to be postponed to a future opportunity after which the results of their special examinations would be communicated.

b. A fragment of gneiss or granite with dark, fine-grained mica, about a centimeter cube, in

c. Mud, which on an average of three samples gave 72 per cent. insoluble in nitric acid, leaving 28 per cent for carbonate of lime in foraminiferal shells, and any other soluble matter which might be present. The species of foraminifera present were left for future enumeration. The mud was, therefore, about three-quarters derived from decomposed rock, and contained specks of mica flakes among the minute sand grains also found in it.

2. From lat. $49^{\circ} 30' N.$, lon. $49^{\circ} 36' W.$, at a depth of 2594 fathoms, were taken on the 3rd July, 1894:—

a. A fragment of rock about $8 \times 4 \times 3 \text{ cm}$. It was a very compact, fine-grained, dark (with a band of light grey) chocolate quartzose felsite in appearance, breaking with a conchoidal fracture, a portion of one side looking as even as if it were ground plane. The light grey band on the opposite side suggested discoloration by weathering, and the conchoidal fracture in this portion was much rougher in its surface texture.

b. A fragment of a water-worn, whitish, cryptocrystalline quartzite pebble about 3 cm in its three dimensions.

c. Mud with small pebbles, containing what suggested the remains of a cœlenterate animal with slender stem, cylindrical body a few

centimeters long, with slender tentacular processes. This material was originally bottled in alcohol which had nearly all evaporated before examination, and the organism was not intact. The mud contained siliceous grains with occasional sponge spicules, &c.

3. From a depth of 30 fathoms, about 15 miles E. N. E. (magnetic) from Flat Point, Sydney, C. B.

a. Thin brachiopod shells, the largest about 28x22mm.

b. What suggested arborescent Polyzoan Zœcia, about 1^{dm} high, the cylindrical spray of branches having a diameter of about 15^{mm}.

c. A sheet of the eggs of a gastropod.

4. From between

lat. 43° 52' N., lon. 58° 53' W. in 500 fathoms,

lat. 43° 53½' N., lon. 58° 59½' W. in 858 fathoms,

and lat. 43° 56' N., lon. 59° 3' W. in 170 fathoms.

A coral, of the form of *caryophyllia*, rising from a thin encrustation partly surrounding a pitch-covered cylinder (Cable) about 3^{cm} in diameter, with a stem about 1^{cm} at the base, gradually expanding until at a height of 4^{cm} it formed an elliptical cup-shaped corallite about 3.5^{cm} and 4.5^{cm} in diameter, filled with numerous septae of unequal height, in one series.

SIXTH ORDINARY MEETING.

Legislative Council Chamber, Halifax, 9th April, 1900.

The PRESIDENT in the chair.

The RECORDING SECRETARY read a communication from the Royal Society of Canada, inviting the Institute to appoint a delegate to attend the nineteenth general meeting of the Society to be held at Ottawa on the 29th of May next. The communication was referred to the Council for action.

PROF. ERNEST HAYCOCK of Acadia College, Wolfville, N. S., read a paper entitled : "Records of Post-Triassic Changes in Kings County, N. S." (See Transactions, p. 287.)

The subject was discussed by DR. GILPIN and MR. MCKAY, and a vote of thanks was presented to the author.

The PRESIDENT, A. H. MACKAY, ESQ., LL. D., read a paper on "A Fresh-Water Sponge from Sable Island." To this species Dr. MacKay proposed to give the name *Heteromeyenya Macouni*. The subject was illustrated by microscopic preparations. (See Transactions, p. 319).

SEVENTH ORDINARY MEETING.

Legislative Council Chamber. Halifax, 14th May, 1900.

The PRESIDENT in the chair.

It was announced that the PRESIDENT, DR. MACKAY, had been appointed delegate to represent the Institute at the forthcoming meeting of the Royal Society of Canada.

It was reported that progress had been made in fitting up a room for the library of the Institute, etc., in the new government building, Hollis Street.

In the absence of the author, DR. MACGREGOR read a paper by PROF. JOHN DAVIDSON, of the University of New Brunswick, Fredericton, on "The Natural History of Money." (See Transactions, p. 179.)

The paper was discussed by COLONEL McSHANE, DR. H. H. READ, FRERERICK P. RONNAN, ESQ., and others, and a vote of thanks was presented to PROF. DAVIDSON for his communication.

A. H. MACKAY, ESQ., LL. D., F. R. S. C., read a paper entitled "Phenological Observations, Canada, 1899." (See Transactions, p. 303.)

A paper by T. C. HEBB, ESQ., B. A., Dalhousie College, "On the Variation of the Rigidity of Vulcanized India-Rubber with Tension," was presented by DR. MACGREGOR. (See Transactions, p. 273)

The following papers were read by title:—"Notes on a Cape Breton Mineral containing Tungsten, and on the effect of washing certain Cape Breton Coals,"—By HENRY S. POOLE, ESQ., F. G. S., Stellarton, N. S. (See Transactions, p. 248.)

"Geological Nomenclature in Nova Scotia,"—By HUGH FLETCHER, ESQ., Geological Survey of Canada. (See Transactions, p. 235.)

A collection of dried plants from the vicinity of Buffalo, U. S. A., made by REV. BROTHER JUNIAN PETER, St. Joseph's Commercial College, Detroit, and presented by him to the Institute, was shewn, and a vote of thanks was passed to BROTHER PETER for his gift.

The council was authorized to receive as having been read by title, any papers that might be offered too late for this meeting. [Under this resolution a paper subsequently submitted by PROF. J. G. MACGREGOR, "On a diagram of Freezing-point Depressions for Electrolytes," was accepted by the Council. (See Transactions, p. 211).]

HARRY PIERS,

Recording Secretary.

TRANSACTIONS

OF THE

Nova Scotian Institute of Science.

SESSION OF 1899-1900.

I.—ON THE RELATION OF THE VISCOSITY OF MIXTURES OF SOLUTIONS OF CERTAIN SALTS TO THEIR STATE OF IONIZATION. — BY JAMES BARNES, B. A., *Dalhousie College, Halifax, N. S.*

(Communicated by Prof. J. G. MacGregor on December 15th, 1899.)

The present paper is the result of a piece of work undertaken at the suggestion of Prof. MacGregor, for the summer vacation of 1899, the object being to find out in the case of mixtures of aqueous solutions of certain electrolytes with a common ion, whether or not it is possible, by the aid of the dissociation conception, to predict the viscosities of the mixtures, when sufficient data as to the viscosities and conductivities of the constituent solutions are available.

The salts selected were sodium chloride, potassium chloride, barium chloride, sodium sulphate, potassium sulphate, and copper sulphate, the viscosities of simple solutions of these salts having been determined by ¹Reyher and ²Wagner, and that of mixtures of them by ³Kanitz, and extensive series of observations on the conductivity by Kohlrausch and by former students of Dalhousie College, being available. As will be seen below I found ⁴Kohlrausch's values of the conductivity sufficient for my purpose.

¹Ztschr. f. phys. Chemie, 2, 744, 1888.

²*Ibid.*, 5, 31, 1890.

³*Ibid.*, 22, 336, 1897.

⁴Kohlrausch u. Holborn: Leitvermögen der Elektrolyte, 1898, pp. 159, 160, tab. 2.

¹Professor MacGregor has pointed out that, both on theoretical grounds and because of the way in which the ionization coefficients and such physical properties as specific gravity, viscosity, etc., in general, vary with the concentration in simple solutions, it is to be expected that the value of any such property, for a simple solution which is so dilute that the dissociated and undissociated molecules may be regarded as without mutual action, will be expressed by the formula :

$$P = P_w + k(1-a)n + l a n, \dots\dots\dots (1)$$

where P is the numerical value of the property for the solution, P_w that of the same property for water under the same physical conditions, n the concentration expressed in gramme-equivalents per unit volume, a the ionization coefficient of the electrolyte in the solution, and k and l constants, called ionization constants.

He has further shown that the value of a property for a mixture of two electrolytes will be given in terms of the values of the ionization constants as determined for the simple solutions, by the expression :

$$P = P_w + \frac{1}{p} \left[\left(k_1(1-a_1)n_1 + l_1 a_1 n_1 \right) \frac{v_1}{v_1 + v_2} + \left(k_2(1-a_2)n_2 + l_2 a_2 n_2 \right) \frac{v_2}{v_1 + v_2} \right] \dots (2)$$

where the n 's are the concentrations of the constituent solutions (the electrolytes being indicated by 1 and 2), the a 's the ionization coefficients of the respective electrolytes in the mixture, the v 's the volumes of the constituent solutions, and p the ratio of the volume of the mixture to the sum of the volumes of the constituent solutions.

The application of the first expression to simple solutions is, as ²Prof. MacGregor has shown, of little theoretical interest; but that of the second to mixtures, because of its being based on the dissociation theory and involving no arbitrary constants, is of very considerable interest. It is the applicability of this expression (2) that the present paper is intended to test with mixtures of solutions of the above-mentioned salts.

¹ Trans. N. S. Inst. Sci., 9, 219, 1896-97.

² Trans. N. S. Inst. Sci., 10, 61 (foot note), 1898-99.

The observations of Reyher, Wagner and Kanitz were made on somewhat stronger solutions than those for which the above expressions might be expected to hold, but they were considered as probably sufficiently dilute to warrant the expectation of an approximate applicability of the expressions.

Simple Solutions.

For the determination of the ionization constants in expressions (1) and (2), one must know the ionization coefficients for the four solutions examined in the case of each salt by Reyher and Wagner. Unfortunately all the observations on the viscosity of these salts were made at 25° C., while all the available conductivity data, from which the ionization coefficients are obtained, were at 18°C., and thus it was necessary either to reduce the viscosity values from 25° to 18° or the conductivity values from 18° to 25°. This latter reduction was carried out, as data for the former were not available. This involved much work; because for the determination of the ionization coefficients at 25°, it was necessary to obtain both the specific molecular conductivity at 25° and the specific molecular conductivity at infinite dilution for 25°.

Determination of the Specific Molecular Conductivity at Infinite Dilution for 25°C.

The value of the specific molecular conductivity at infinite dilution for 25° for each salt was obtained from ¹Kohlrausch's value at 18° by aid of ²Déguisne's data. These data were employed in obtaining the specific molecular conductivity at 25° from the values at 18°, for the three weakest solutions given in ³Kohlrausch's and Déguisne's tables; and the ratio $\frac{\mu_{25} - \mu_{18}}{\mu_{18}}$ was then determined, where μ_{25} and μ_{18} are the specific molecular conductivity at 25° and 18° respectively.

Table I gives the values thus obtained. The concentrations are expressed in gramme-equivalents per litre, and the specific molecular conductivities in terms of this unit and of 10⁻⁴ times ⁴Kohlrausch's new unit of conductivity (ohm⁻¹ cm.⁻¹).

¹ Kohl. u. Holb., *loc. cit.*, p. 200, tab. 8.

² *Ibid.*, p. 195, tab. 7.

³ *Ibid.*, pp. 159, 160, tab. 2.

⁴ *Ibid.*, p. 1.

TABLE I.

Concentration.	Sp. Mol. Cond. at 18° C. (μ_{18})	Sp. Mol. Cond. at 25° C. (μ_{25})	$\mu_{25} - \mu_{18}$
			μ_{18}
Na. Cl.			
.0005	1085	1262	.163
.0002	1092	1270	.163
.0001	1097	1276	.163
K Cl			
.0005	1283	1484	.156
.0002	1291	1494	.157
.0001	1295	1499	.157
$\frac{1}{2}$ Ba Cl ₂ .			
.0005	1183	1375	.162
.0002	1198	1394	.163
.0001	1205	1402	.163
$\frac{1}{2}$ K ₂ SO ₄ .			
.0005	1308	1516	.159
.0002	1327	1540	.160
.0001	1335	1549	.160
$\frac{1}{2}$ Na ₂ SO ₄ .			
.0005	1083	1266	.169
.0002	1096	1281	.169
.0001	1105	1292	.169

As the ratio $\frac{\mu_{25}-\mu_{18}}{\mu_{18}}$ was thus found to be constant for the two most dilute solutions of every salt, and as these solutions are very dilute, this ratio may be assumed to approximately hold for infinite dilution. Observations on the conductivity of weaker solutions at different temperatures were not at hand; and the writer used the value of this ratio for the solution of concentration .0001 for the calculation of the specific molecular conductivity at infinite dilution for 25° C.

The following Table II gives the values of the specific molecular conductivity at infinite dilution for 25° C. as thus obtained from the values at 18° C. In the case of copper sulphate this method could not be employed for want of data. A somewhat doubtful value obtained by ¹Bredig was therefore used. The conductivities are expressed as in Table I.

TABLE II.

Electrolyte.	Specific Molecular Conductivity at Infinite Dilution.	
	18° C.	25° C.
Na Cl.	1103	1283
K Cl.	1312	1519
$\frac{1}{2}$ Ba Cl ₂	1232	1433
$\frac{1}{2}$ K ₂ SO ₄	1350	1566
$\frac{1}{2}$ Na ₂ SO ₄	1141	1334
$\frac{1}{2}$ Cu SO ₄. ....	.....	1423

*Determination of the Ionization Coefficients at 25° C.
for Simple Solutions.*

The ionization coefficient for a simple solution is taken to be the ratio of the specific molecular conductivity to the specific

¹ Ztschr. f. phys. Chem., 13, 220, 1894,

molecular conductivity at infinite dilution. Before this ratio could be found for 25°C. it was necessary to determine the values of the specific conductivity at 25° from ¹Kohlrausch's values at 18° by means of ²Déguisne's and ³Kohlrausch and Grotrian's temperature coefficients. The concentrations of solutions of the salts for which Kohlrausch gives conductivity values, did not in all cases correspond to the concentrations of solutions for which Reyher and Wagner determined the viscosity. In such cases (concentrations 0.25 and 0.125), the values of the specific conductivities at 25° were obtained by interpolation.

Table III gives both the values of the specific conductivity at 25°C. determined as above from the values at 18°, and the calculated ionization coefficients at 25°. Only those coefficients are given which are necessary in the calculation of the viscosities. Under copper sulphate are given a few conductivity values of higher concentration, these being necessary for the determination of the ionization coefficients in the mixtures by the method used. The concentrations are expressed as in Table I, and conductivities in terms of 10^{-4} times Kohlrausch's new unit.

¹ Kohl. u. Holb., *loc. cit.*, p. 159, table 2.

² *Loc. cit.*

³ Kohl. u. Holb., p. 145, tab. 1.

TABLE III.

Concentration.	Specific Conductivity at 18° C.	Specific Conductivity at 25° C.	Ionization Coefficients at 25° C.
Na Cl.			
1.0	744.0	862	.672
0.5	404.5	469	.732
0.3	255.6	296	.....
0.25	.. ...	252	.786
0.2	176.4	205	.....
0.125	.....	131	.817
0.1	92.5	107	.....
K Cl.			
1.0	982.0	1128	.743
0.5	511.5	588	.774
0.3	315.9	363	.... .
0.25	.....	308	.811
0.2	215.4	248	.....
0.125	.....	159	.838
0.1	111.9	129	.....
$\frac{1}{2}$ Ba Cl ₂ .			
1.0	703	811	.566
0.5	388	448	.624
0.3	249	287	.....
0.25	.....	245	.684
0.2	173.4	200	.....
0.125	.....	130	.726
0.1	92.2	106	.... .

TABLE III.—(Continued.)

Concentration.	Specific Conductivity at 18° C.	Specific Conductivity at 25° C.	Ionization Coefficients at 25° C.
$\frac{1}{2} \text{K}_2 \text{SO}_4$			
1.0	718.0	827	.528
0.5	393.5	453	.578
0.3	253.2	292	.....
0.25	.....	251	.640
0.2	177.8	205	.....
0.125	.....	135	.690
0.1	95.9	111	.....
$\frac{1}{2} \text{Na}_2 \text{SO}_4$			
1.0	508.0	591	.443
0.5	298.5	347	.520
0.3	199.8	230	.....
0.25	.....	201	.604
0.2	142.8	166	.....
0.125	.....	110	.662
0.1	78.4	91.4	.....
$\frac{1}{2} \text{Cu SO}_4$			
2.631	458	534	.....
2.194	421	489	.....
1.0	258	297	.209
0.5	154	177	.249
0.3	106.5	122	.....
0.25	.....	107	.302
0.2	78.4	89.9	.....
0.125	.....	61.7	.347
0.1	45.0	51.6	.....

Determination of the Ionization Constants.

Table IV gives the values of the ionization constants (k and l) determined by the method of least squares from the data given in Tables III and V, the observed values of the viscosity of the four solutions of each salt being used. The relative magnitude and the sign of the ionization constants would seem to show that the undissociated molecules exert the greater influence in increasing the viscosity, while the free ions have in some cases a diminishing effect.

TABLE IV.

Electrolyte.	k .	l .
Na Cl.	+0.11213	+0.089765
K Cl.	+0.30645	-0.12289
$\frac{1}{2}$ Ba Cl ₂ .	+0.20327	+0.061009
$\frac{1}{2}$ K ₂ SO ₄ .	+0.21347	+0.0088236
$\frac{1}{2}$ Na ₂ SO ₄ .	+0.30418	+0.13348
$\frac{1}{2}$ Cu SO ₄ .	+0.46500	-0.058144

Results of Calculations on Simple Solutions.

Table V gives a comparison of the calculated and observed values of the viscosity of simple solutions, the calculated values being determined by expression (1) with the ionization coefficients and ionization constants, as given in the above tables. In this table all the viscosity results are relative to water at 25°C., and the concentrations are expressed as in Table I.

TABLE V.
VISCOSITY AT 25° C.

Concentration.	Observed Value.	Calculated Value.	Difference.
Na Cl. (Reyher.)			
1.0	1.0973	1.0971	-0.0 ₃ 2
0.5	1.0471	1.0479	+0.0 ₃ 8
0.25	1.0239	1.0236	-0.0 ₃ 3
0.125	1.0126	1.0117	-0.0 ₃ 9

TABLE V.—(Continued).

Concentration.	Observed Value.	Calculated Value.	Difference.
K Cl. (Wagner.)			
1.0	.9872	.9874	+ 0.0 ₃ 2
0.5	.9874	.9871	— 0.0 ₃ 3
0.25	.9903	.9896	— 0.0 ₃ 7
0.125	.9928	.9933	+ 0.0 ₃ 5
$\frac{1}{2}$ Ba Cl ₂ . (Wagner.)			
1.0	1.1228	1.1228	\pm 0.0 ₃ 0
0.5	1.0572	1.0572	\pm 0.0 ₃ 0
0.25	1.0263	1.0265	+ 0.0 ₃ 2
0.125	1.0128	1.0125	— 0.0 ₃ 3
$\frac{1}{2}$ K ₂ SO ₄ . (Wagner.)			
1.0	1.1051	1.1054	+ 0.0 ₃ 3
0.5	1.0486	1.0476	— 0.0 ₂ 1
0.25	1.0206	1.0206	\pm 0.0 ₃ 0
0.125	1.0078	1.0090	+ 0.0 ₂ 12
$\frac{1}{2}$ Na ₂ SO ₄ . (Wagner.)			
1.0	1.2291	1.2286	— 0.0 ₃ 5
0.5	1.1058	1.1078	+ 0.0 ₂ 2
0.25	1.0522	1.0502	— 0.0 ₂ 2
0.125	1.0235	1.0239	+ 0.0 ₃ 4
$\frac{1}{2}$ Cu SO ₄ . (Wagner.)			
1.0	1.3580	1.3556	— 0.0 ₂ 24
0.5	1.1603	1.1675	+ 0.0 ₂ 72
0.25	1.0802	1.0767	— 0.0 ₂ 35
0.125	1.0384	1.0354	— 0.0 ₂ 30

As both Reyher and Wagner regard their results as affected by a possible error of about ± 3 in the third decimal place, it is seen that the agreement between the calculated and observed values for all the salts except copper sulphate is very satisfactory, the differences being well within the limit of experimental error. In the case of copper sulphate, the agreement is not so satisfactory. But it was noticed on plotting the observed values against the concentration that the points do not lie on a smooth curve, and that the point corresponding to the concentration 0.5 is at quite a distance from this curve, which leads one to think that this observed value cannot be correct. The poor agreement in this case might also be partly due to the doubtful value of the specific molecular conductivity at infinite dilution used. Thus it seems that for all the salts examined, copper sulphate perhaps excepted, expression (1) gives the viscosity of a solution within the limit of experimental error throughout a concentration range of 1.0 to 0.125.

Mixtures of Solutions.

As there is no change of volume on mixing the constituent solutions of the above electrolytes of the concentrations given below¹, and as the solutions mixed were of equal volume and also equimolecular, the expression (2) for the value of a property in the case of a mixture of two electrolytes with a common ion, reduces to :

$$P = P_w + \frac{n}{2} [k_1 (1 - a_1) + l_1 a_1 + k_2 (1 - a_2) + l_2 a_2] \quad (3)$$

where n is the concentration of the solutions and the k 's and l 's have the values obtained above for simple solutions of the respective electrolytes. For the application of this equation to the calculation of the viscosity of a mixture, all the quantities required are known except the a 's, the ionization coefficients in the mixture.

¹ See Trans. N. S. Inst. Sci., 9, 125, 1895-96; also 9, 297 and 310, 1897-98.

Determination of Ionization Coefficients in the Mixture.

The method proposed by ¹Prof. MacGregor for finding the ionization coefficients in a mixture of two electrolytes having an ion in common, is by solving graphically the following equations :

$$\frac{a_1}{V_1} = \frac{a_2}{V_2}, \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$N_1 V_1 + N_2 V_2 = 1, \quad . \quad . \quad . \quad . \quad (5)$$

$$\frac{a_1}{V_1} = f_1(V_1), \quad . \quad . \quad . \quad . \quad (6)$$

$$\frac{a_2}{V_2} = f_2(V_2), \quad . \quad . \quad . \quad . \quad (7)$$

where the electrolytes are denoted by 1 and 2, the concentrations (in gramme-equivalents per litre) of the mixture with respect to them by N_1 and N_2 respectively, their ionization coefficients by a_1 and a_2 , and their regional dilutions (in litres per gramme equivalent) by V_1 and V_2 , the regional dilutions being the dilutions of the electrolytes in the regions which they are supposed to occupy in the mixture, or the dilutions of the constituent isohydric solutions.

His graphical mode of solving these equations involves the drawing of dilution-ionic-concentration curves, which, as they have great curvature for moderately dilute solutions, cannot be drawn with great accuracy unless a large number of observations of the conductivity are available. As mentioned above, extensive series of observations of the conductivity in the case of the salts under consideration were available; but they were all made at 18° C. and required therefore to be reduced to 25° C. before they could be used. In order to reduce this labour as much as possible I devised another mode of solution which requires only a comparatively small number of observations. It is based on the fact that the specific-conductivity-concentration

curve of an electrolyte exhibits only slight curvature and can therefore be drawn with fair accuracy from a small number of observations.

The above equations may be expressed in terms of specific conductivity and concentration as follows. Since

$$\frac{\alpha_1}{V_1} = \frac{\mu_1}{V_1 \mu_{\infty 1}} = \frac{k_1}{\mu_{\infty 1}}, \quad . \quad . \quad . \quad (8)$$

and
$$\frac{\alpha_2}{V_2} = \frac{k_2}{\mu_{\infty 2}}, \quad . \quad . \quad . \quad . \quad (9)$$

where k_1 and k_2 are the specific conductivities of the electrolytes in the regions which they respectively occupy in the mixture, and the μ_{∞} 's the specific molecular conductivities at infinite dilution for each electrolyte, equation (4) becomes :

$$\frac{k_1}{\mu_{\infty 1}} = \frac{k_2}{\mu_{\infty 2}},$$

or,
$$k_1 = \frac{\mu_{\infty 1}}{\mu_{\infty 2}} k_2. \quad . \quad . \quad . \quad . \quad (10)$$

From equation (5) we obtain :

$$\frac{N_1}{C_1} + \frac{N_2}{C_2} = 1, \quad . \quad . \quad . \quad . \quad (11)$$

where C_1 and C_2 are the regional concentrations. Equations (6) and (7) are based on the fact that at a definite temperature the conductivity is a function of the concentration alone. They therefore take the following forms :

$$k_1 = f_1(C_1), \quad . \quad . \quad . \quad . \quad (12)$$

and
$$k_2 = f_2(C_2). \quad . \quad . \quad . \quad . \quad (13)$$

There are thus four equations (10—13) for the determination of the four unknown quantities : k_1 , k_2 , C_1 , and C_2 .

These equations can be solved graphically. Equation (12) is employed by drawing a curve having as abscissæ the values of the specific conductivities and corresponding values of the concentrations as ordinates. Before equation (13) is used the values

of the conductivities are multiplied by the constant $\frac{\mu_{\infty 1}}{\mu_{\infty 2}}$. Then these new values are plotted against the corresponding concentrations, on the same coordinate paper, to the same scale as employed for equation (12). From these two curves one finds by inspection two points, one on each curve, having a common abscissa, according to equation (10), and ordinates (C_1 and C_2) such that by substituting their values in equation (11) it will be satisfied. These points can be found after two or three trials. Thus one has determined k_1 , C_1 , and C_2 ; k_2 being found by multiplying k_1 by the constant $\frac{\mu_{\infty 2}}{\mu_{\infty 1}}$. The a 's are now obtained from equations (8) and (9); for the reciprocals of the C 's give the V 's.

Results of the Calculations on Mixtures.

The following Table VI contains the requisite data for the calculation, by formula (3), of the viscosity of mixtures of solutions of the salts under consideration; and it shows the agreement of the values thus calculated with the observed values. The ionization coefficients of the salts in the mixture are determined as above and the concentrations are expressed as in the former tables.

TABLE VI.

VISCOSITY AT 25°. (KANITZ).

Concentration Constituent Solutions.		Ionization Coefficients in Mixture.		Observed Values.	Calculated Values.	Differ- ence.
K Cl.	Na Cl.	K Cl.	Na Cl.			
1.0	1.0	.745	.667	1.0390	1.0419	+ 0.0 ₂ 29
0.5	0.5	.775	.728	1.0180	1.0173	- 0.0 ₃ 7
0.25	0.25	.807	.783	1.0070	1.0069	- 0.0 ₃ 1
K Cl.	$\frac{1}{2}$ Ba Cl ₂ .	K Cl.	$\frac{1}{2}$ Ba Cl ₂ .			
1.0	1.0	.756	.552	1.0429	1.0533	+ 0.0101
0.5	0.5	.779	.613	1.0159	1.0220	+ 0.0 ₂ 61
0.25	0.25	.811	.675	1.0049	1.0082	+ 0.0 ₂ 33
$\frac{1}{2}$ K ₂ SO ₄ .	$\frac{1}{2}$ Na ₂ SO ₄ .	$\frac{1}{2}$ K ₂ SO ₄ .	$\frac{1}{2}$ Na ₂ SO ₄ .			
1.0	1.0	.535	.434	1.1660	1.1670	+ 0.0 ₂ 1
0.5	0.5	.597	.517	1.0773	1.0768	- 0.0 ₃ 5
0.25	0.25	.641	.604	1.0334	1.0354	+ 0.0 ₂ 2
$\frac{1}{2}$ K ₂ SO ₄ .	$\frac{1}{2}$ Cu SO ₄ .	$\frac{1}{2}$ K ₂ SO ₄ .	$\frac{1}{2}$ Cu SO ₄ .			
1.0	1.0	.559	.152	1.2240	1.2423	+ 0.0183
0.5	0.5	.612	.210	1.1060	1.1107	+ 0.0 ₂ 47
0.25	0.25	.668	.256	1.0485	1.0510	+ 0.0 ₂ 25

Kanitz regards his observed values as affected by a possible error of ± 3 in the third decimal place. Considering the many calculations necessary to obtain the calculated values,—first, in finding the specific molecular conductivity at infinite dilution for 25°C., and also ionization coefficients at 25° from data at 18°, and then in the determination of the ionization coefficients of the salts in the mixture by the graphical method,—the agreement between the observed and the calculated values (calculated,

it should be noted, with the ionization constants obtained for the simple solutions), is very satisfactory, especially in the case of solutions of potassium chloride and sodium chloride and solutions of potassium sulphate and sodium sulphate, where the differences are all within the limit of experimental error. In the case of the stronger solutions of potassium chloride and barium chloride and of potassium sulphate and copper sulphate, the differences are not within the limit of error; but a close agreement, as was pointed out in the beginning, could not be expected. It will be noticed, however, that the differences in these cases diminish and approach the experimental error as concentration diminishes. Observations on the viscosity of weaker solutions of these salts were not available.

From these results, therefore, it may be concluded, that the viscosity of mixtures of dilute solutions of the salts under consideration can be predicted, by the aid of the dissociation theory, within the limit of experimental error, from data as to the viscosity and conductivity of the constituent solutions only.

II.—ON THE CALCULATION OF THE CONDUCTIVITY OF AQUEOUS SOLUTIONS CONTAINING HYDROCHLORIC AND SULPHURIC ACIDS.—BY JAMES BARNES, B. A., *Dalhousie College, Halifax, N. S.*

(Communicated by Prof. J. G. MacGregor, on the 15th January, 1900.)

The prediction of the conductivity of dilute aqueous solutions containing two electrolytes, which have one ion in common, has been shown to be possible, according to the dissociation theory, when the electrolytes are salts, or a salt and a diatomic acid such as hydrochloric acid.¹ The experiments described in the present paper were made, at Prof. MacGregor's suggestion, in order to ascertain if it is possible to make the prediction in the case of solutions formed by mixing hydrochloric and sulphuric acid solutions.

The attempt to calculate the conductivity of a complex solution containing sulphuric acid as one constituent is of special interest because of the fact that it is supposed to have a mode of ionization which varies with the concentration of the solution, its molecules in dilute solutions dissociating into 2H and SO_4 , but in stronger solutions partly into H and H SO_4 . It is of course impossible to calculate the conductivity of a complex solution, one of the constituents of which has a mixed mode of ionization. I have therefore assumed that the mode of ionization in the moderately dilute solutions which I examined would be the same as it is usually supposed to be at great dilution.

The conductivity of a mixture of two solutions of electrolytes 1 and 2, with a common ion and definite modes of ionization

¹ MacGregor: Trans. N. S. Inst. Sci., 9, 101, 1895-6.

McIntosh: *Ibid.*, 9, 120, 1895-6.

Archibald: *Ibid.*, 9, pp. 291, 307, 1897-8.

McKay: *Ibid.*, 9, 321, 1897-8.

Barnes: *Ibid.*, 10, 49, 1898-9.

is given, according to the dissociation theory, by the equation:

$$k = \frac{1}{p(v_1 + v_2)} (a_1 v_1 n_1 \mu_{\infty 1} + a_2 v_2 n_2 \mu_{\infty 2}), \dots (A)$$

where v_1, v_2 are the volumes, and n_1, n_2 the concentrations of the solutions mixed, $\mu_{\infty 1}, \mu_{\infty 2}$ the specific molecular conductivities of simple solutions of the electrolytes at infinite dilution, a_1 and a_2 the ionization co-efficients of the respective electrolytes in the mixture, and p the ratio of the volume of the mixture to the sum of the volumes of the constituent solutions.

¹ Prof. MacGregor has shown that the ionization coefficients in a mixture of this kind may be found by the solution of four equations, and I have pointed out in a former paper² that by throwing these equations into other forms and applying a graphical method they may be solved with little trouble, even in cases in which but few observations of the conductivity of simple solutions of the electrolytes in the mixtures are available. The forms of the equations referred to are as follows:

$$\begin{aligned} k_1 &= \frac{\mu_{\infty 1}}{\mu_{\infty 2}} k_2, \\ \frac{N_1}{C_1} + \frac{N_2}{C_2} &= 1, \\ k_1 &= f_1(C_1), \\ k_2 &= f_2(C_2), \end{aligned}$$

where the k 's and C 's are the regional conductivities and regional concentrations, and the N 's the concentrations of the mixture, with respect to the electrolytes 1 and 2 respectively. By the regional conductivity and the regional concentration of an electrolyte in a mixture are meant the conductivity and concentration of the portion or region of the mixture which the one electrolyte may be supposed to occupy to the exclusion of the other. If there is no change of volume on mixing, they are the conductivities and concentrations of the isohydric constituents of the mixture.

¹ Trans. N. S. Inst. Sci., 10, 63, 1898-9.

² Trans. N. S. Inst. Sci., 10, 113, 1899-1900.

The method of obtaining the ionization coefficients by means of these equations is described in my former paper, the first stage in the process being the determination of the k 's and C 's. In the calculation of the conductivity, however, we save labour if instead of determining the ionization coefficients, we express the conductivity in terms of the k 's and C 's.

For this purpose we have :

$$\alpha_1 = \frac{k_1}{C_1 \mu_{\infty 1}},$$

and

$$\alpha_2 = \frac{k_2}{C_2 \mu_{\infty 2}}.$$

Equation (A) thus becomes :

$$k = \frac{1}{p(v_1 + v_2)} \left(\frac{k_1 n_1 v_1}{C_1} + \frac{k_2 n_2 v_2}{C_2} \right).$$

In my experiments p was found to be practically equal to unity, and the volumes of the solutions mixed were in all cases equal. Hence the above equation becomes :

$$k = \frac{1}{2} \left(\frac{k_1 n_1}{C_1} + \frac{k_2 n_2}{C_2} \right) \dots \dots \dots (B)$$

The work involved in finding k by means of equation (B), included the following:—(1) The preparation and analysis of series of simple solutions of both acids, and the preparation of the mixtures; (2) observations on the specific gravity of the simple constituent solutions and their mixtures; (3) the measurement of the conductivity of series of simple solutions; (4) the measurement of the conductivity of mixtures of solutions; (5) the determination of the regional conductivity and regional concentration of the electrolytes in the mixtures; (6) the calculation by the aid of these data, of the conductivity of the mixtures.

The observations were carried out in the Physical and Chemical Laboratories of Dalhousie College, Halifax, during the spring and autumn of 1899.

Experimental Methods.

The hydrochloric acid was obtained from Eimer & Amend, and the sulphuric from Merck & Co. Both were guaranteed chemically pure. The redistilled water used in the preparation of the solutions was obtained by the method described in a former ¹paper, and it had a conductivity ranging from 0.95×10^{-6} to 1.01×10^{-6} expressed in ²Kohlrausch's new unit ($\text{ohm}^{-1} \text{ cm.}^{-1}$).

The amount of hydrochloric or sulphuric acid in a solution was determined volumetrically by means of aqueous solutions of potassium hydroxide, the strength of these being determined daily by titration with known quantities of dry oxalic acid. Phenol-phthalein was the indicator used. The potassium hydroxide solutions were kept in bottles with stoppers, each containing a soda lime tube. The pipettes, burettes and flasks were calibrated and used as described in the paper referred to above. The specific gravity at 18°C. was determined for many of the simple solutions with a pyknometer of the Ostwald-Sprengel form. The comparison of the values thus obtained with the values as given by Kohlrausch, acted as a check upon the concentration as determined above.

Kohlrausch's method with the alternating current and telephone was employed in the measurement of the conductivity.

The bath used to obtain a constancy of temperature, for a time sufficient to make the determination of the resistance in, contained tap water kept continually stirred by a mechanical stirrer driven by one of Henrici's small hot air motors. This motor worked without noise and on this account was found more serviceable than the hydraulic motor formerly employed. The thermometer used could be read to a hundredth of a degree, and had been tested at the Physikalisch-Technische Reichsanstalt, Berlin.

The resistance of the solutions was measured in a U-shaped cell having electrodes of stout platinum foil connected by thick

¹Trans. N. S. Inst. Sci., 10, 49, 1898-9.

²Kohlrausch u. Holborn: *Leitvermögen der Elektrolyte*, 1898, p. 1.

platinum wires to the ebonite covers. These electrodes were platinized in the solution proposed by ¹Lummer and Kurlbaum. The reduction factor by which the conductivities obtained in this cell are reduced to the standard employed by Kohlrausch, was obtained by comparing the value of the conductivities of two solutions of pure potassium chloride, twice recrystallized, of different concentrations, with values given by ²Kohlrausch for the same concentrations of the same salt. The ratio of Kohlrausch's value to the observed value gives the reduction factor. It was always determined before and after a series of observations, and was found to be the same in value at both times.

Solutions of different concentrations of each acid were prepared and carefully analysed. Fifty cubic centimetres of one of these solutions was placed in the electrolytic cell at a time, and two successive dilutions prepared in the cell by the addition of known volumes of water at 18°C. Then the other prepared solutions were introduced in order, and the same process of dilution repeated till a sufficient number of conductivity values had been obtained. In the case of mixtures, equal volumes (fifty cubic centimetres) of the constituent solutions were mixed at 18° C., and the mixture was then placed in the cell.

For a more detailed description of some of the above instruments and methods, see my former paper on conductivity.

Results of the Conductivity Observations on Simple Solutions.

It is necessary for the determination of the regional conductivities (k) and the regional concentrations (C) in the mixture (see my former paper),³ to draw curves showing the relation of conductivity to the concentration for each acid. In the case of one of the electrolytes, (hydrochloric acid was selected), the values of the conductivity must be multiplied by a constant before plotting, this constant being the ratio of the specific molecular conductivities at infinite dilution for the two

¹ Wied. Ann., 66, 315, 1897.

² Kohl. u. Holb., *loc. cit.*, p. 159, tab. 2.

³ Trans. N. S. Inst. Sci., 10, 113, 1899-1900.

acids. Kohlrausch's latest determinations¹ of the values of the specific molecular conductivity at infinite dilution at 18° C. for the two acids were used, viz.: for hydrochloric acid, 3774, and for sulphuric acid, 3955, both expressed in terms of 10^{-4} times Kohlrausch's new unit ($\text{ohm}^{-1} \text{ cm.}^{-1}$). Therefore, the ratio is 1.048.

Table I gives the data, obtained from the conductivity observations, for the drawing of these curves. The concentrations are expressed in terms of gramme equivalent per litre at 18°C. The atomic weights used are relative to Oxygen (16.00), and the same as employed by ²Kohlrausch. The specific conductivities are those at 18°C, expressed in terms of 10^{-4} times Kohlrausch's new unit ($\text{ohm}^{-1} \text{ cm.}^{-1}$).

TABLE I.

H Cl. (36.46.)			$\frac{1}{2}$ H ₂ SO ₄ . (49.04.)	
Concentration (n_1).	Specific Conductivity (k_1).	$\frac{\mu_{\infty 2}}{\mu_{\infty 1}} k_1$	Concentration (n_2).	Specific Conductivity (k_2).
2.66	6018.	6305.	4.11	6158.
2.13	5281.	5534.	2.95	4948.
1.74	4627.	4848.	2.20	3947.
1.42	3994.	4185.	1.74	3255.
1.02	3055.	3201.	1.28	2472.
.716	2268.	2376.	.890	1779.
.502	1640.	1718.	.523	1070.
.344	1148.	1203.	.452	932.5
.265	898.3	941.2	.304	637.4
.188	645.3	676.2	.197	421.8
.126	439.7	460.8	.108	241.5
.0951	334.9	350.9	.0967	218.8
.0810	287.9	301.6	.0603	148.4
.0559	201.0	210.6	.0352	93.77
.0356	129.3	135.5	.....	.....
.0262	94.67	99.20	.....	.....

¹ Wied. Ann., 50, 385, 1893.² Kohl. u. Holb., *loc. cit.*, p. 205, tab. 14.

Determination of p.

When equal volumes of simple solutions are mixed the ratio expressed by p is equal to the ratio of the specific gravity of the mixture to the mean specific gravity of the constituent solutions. Table II shows that the ratio is practically equal to unity for the most concentrated solutions examined.

TABLE II.

SIMPLE SOLUTIONS.					Sp. Gr. of Mixture at 18°C.
Concentration.		Specific Gravity at 18°C.		Mean Sp. Gr.	
H Cl.	$\frac{1}{2}$ H ₂ SO ₄ .	H Cl.	$\frac{1}{2}$ H ₂ SO ₄ .		
3.05	2.95	1.0525	1.0912	1.0719	1.0720
2.13	1.74	1.0371	1.0549	1.0460	1.0462
1.02	“	1.0182	“	1.0366	1.0365
.502	“	1.0091	“	1.0320	1.0319

Results of the Observations and Calculations of the Conductivity of Mixtures.

Table III contains the results of the observations and the calculations, by means of the data given therein, of the conductivity of mixtures of the acids under consideration. The regional concentration k_1 of the hydrochloric acid may be obtained from the value k_2 by means of the expression

$$k_1 = \frac{\mu_{\infty 1}}{\mu_{\infty 2}} k_2,$$

where k_2 is the regional concentration of the sulphuric acid. The specific molecular conductivities at infinite dilution have the values given above. In this table the conductivities and concentrations are expressed as in Table I. The differences between the calculated and observed values of the conductivity are given as percentages of observed values.

TABLE III.

Concentrations, Constituent Solutions.		Regional Conductivity of $\frac{1}{2}$ H ₂ SO ₄ (<i>k</i> ₂).	Regional Concentrations.		Specific Conductivity of Mixture.		Difference Per Cent.
H Cl. (<i>n</i> ₁).	$\frac{1}{2}$ H ₂ SO ₄ (<i>n</i> ₂).		H Cl. (<i>C</i> ₁).	$\frac{1}{2}$ H ₂ SO ₄ (<i>C</i> ₂).	Calculated Value.	Observed Value.	
3.80	2.95	6522.	2.83	4.50	6324.	6252.	+1.15
3.05	"	6013.	2.44	3.95	5840.	5784.	+ .97
1.74	"	4905.	1.77	2.92	4786.	4763.	+ .48
.0810	"	2948.	.925	1.55	2938.	2918.	+ .70
.804	.917	2240.	.669	1.15	2178.	2169.	+ .41
.328	"	1495.	.432	.739	1469.	1464.	+ .34
.0521	"	1036.	.292	.503	1033.	1035.	— .19
1.64	.291	2910.	.907	1.53	2788.	2779.	+ .32
1.02	"	2018.	.596	1.02	1936.	1934.	+ .10
.804	"	1638.	.487	.831	1606.	1607.	— .06
.328	"	886.0	.249	.429	857.3	856.7	+ .07
.0810	"	459.1	.125	.215	452.7	454.7	— .44
1.74	.0352	2832.	.880	1.48	2705.	2704.	+ .04
.502	"	927.8	.261	.450	888.0	889.6	— .18
.0951	"	219.2	.0581	.0967	211.1	211.8	— .33
.0810	"	194.7	.0515	.0823	187.8	188.3	— .27
.0521	"	143.1	.0376	.0575	138.4	138.5	— .08
.0264	"	96.65	.0256	.0363	94.43	94.54	— .12

In this table it will be noticed in the first series of observations, where the concentration of the constituent solution of sulphuric acid is constant, while the constituent solution of hydrochloric acid has a variable concentration, that the calculated values are all greater than the observed, and that the differences gradually increase as the concentration of the hydrochloric acid increases. This is also true for the second and third series, except in the case of the weaker hydrochloric acid solutions where the calculated is now less than the observed value. Prof. MacGregor has shown in a note to my former ¹paper, in which I drew attention to a regular progression similar to the above for series of solutions of potassium chloride and potassium sulphate, which were for the most part of moderate concentration, that the regular progression observed may be due to two sources of error. The second source, namely, the impossibility of drawing with perfect accuracy the dilution-ionic-concentration curves, has, I think, been considerably reduced, for in place of drawing these curves, which for moderate concentration curve quite rapidly, concentration-specific-conductivity curves were employed, these curves having but slight curvature and being thus easily interpolated. The other source of error, namely, the using for the value of the ionization coefficient the quotient of the specific molecular conductivity by the specific molecular conductivity at infinite dilution, still remains. In the above fourth series where the first two mixtures are of moderate concentration and the other four may be called dilute solutions, this regular progression has disappeared and the differences are all negative, except in the first mixture. The disappearance of the progression is consistent with its being due to the above sources of error; for in dilute solutions they both produce a very small effect upon the result. Two reasons may be assigned for the signs being all negative in the fourth series:—(1) The use of the above values of the specific molecular conductivity at infinite dilution; for if either of the values used should not be correct then it would clearly produce an error of the same sign

¹ *Loc. cit.*

in all the calculated values of the conductivity. There is also (2) the possibility referred to above, of the sulphuric acid breaking up not only into ions of 2H and SO_4 , but also into H and H SO_4 .

It is also possible by plotting the above series to obtain series of mixtures having a constant concentration for the constituent hydrochloric acid solutions and variable concentrations for the sulphuric acid constituent solutions; and it will be found in series of this kind that the same regular progression is exhibited as in the above. It may be well to note that in the last three series of the above Table where the sign of the difference changes, this change happens for all when the average concentration of the mixture is about 0.6 gramme-equivalents.

Finally, since my experiments are estimated as affected by an error which may amount to about ± 0.3 per cent., it is seen in the table that as the differences for the three last series are all within or in a few cases but little beyond this error, it may be concluded that the conductivity of mixtures of dilute solutions of hydrochloric and sulphuric acid can be calculated within the limit of my experimental error, by the expression of the dissociation theory and on the assumption that the sulphuric acid dissociates into 2H and SO_4 as ions, up to an average concentration of about 0.5 in cases in which the concentration with respect to sulphuric acid is relatively large, and up to an average concentration of about 0.9 in cases in which the concentration with respect to this acid is relatively small.

III.—ON THE DEPRESSION OF THE FREEZING-POINT BY MIXTURES OF ELECTROLYTES.—BY JAMES BARNES, B. A., *Dalhousie College, Halifax, N. S.*

(Communicated by Professor J. G. MacGregor on March 12th, 1900.)

In a ¹paper communicated last winter to this Society, Mr. E. H. Archibald described experiments he had made to test the ionization coefficients, obtained by ²Prof. MacGregor's method, for mixtures of equimolecular solutions of two electrolytes having an ion in common. With these coefficients and Van't Hoff's constant as data, he calculated the depression of the freezing-point of the mixtures; and he then compared the calculated with the experimental values. It was found that the difference between these values was, in general, equal to the arithmetic mean of the differences between the calculated and experimental values of the depressions of the constituent simple solutions, and the test was therefore concluded to be satisfactory.

At Prof. MacGregor's suggestion, I undertook similar experiments with mixtures, not of equimolecular solutions, but of solutions of different concentrations. The electrolytes selected were potassium chloride, sodium chloride, and hydrochloric acid.

In the case of mixtures of solutions which are not equimolecular Mr. Archibald's method of testing the ionization coefficients is not applicable. I found it necessary, therefore, to obtain an expression for the depression of the freezing-point for such mixtures in terms of the ionization coefficients.

In a simple solution containing n gramme-molecules of an electrolyte per litre, if α is the ionization coefficient, the number of dissociated molecules is $n\alpha$ and the number of undissociated $(1-\alpha)n$. If a molecule of this electrolyte breaks down

¹ Trans. N. S. Inst. Sci., 10, 33, 1898-99.

² *Ibid.*, 9, 101, 1895-96.

into m ions, then the number of free ions is $n m a$, and therefore the total number of undissociated molecules and free ions in this solution is

$$(1-a)n + n m a, \text{ or } n(1+a(m-1)).$$

On the assumption that a free ion produces the same amount of depression of the freezing-point as a molecule, and that in a solution the molecules are so far apart that no association of molecules occurs, if δ is the depression of the freezing-point and M the molecular depression, *i. e.*, the depression produced by one gramme-molecule or one gramme-ion, we have

$$M = \frac{\delta}{n(1+a(m-1))} \dots\dots\dots (1)$$

In the case of mixtures of simple solutions, according to the above assumption, Δ the depression of the freezing-point will be represented by the expression:—

$$\Delta = [M_1 N_1 (1+a_1(m_1-1)) + M_2 N_2 (1+a_2(m_2-1)) + \dots] \dots (2)$$

where 1, 2, etc., denote the electrolytes, the m 's the numbers of ions into which the molecules of the respective electrolytes break down, the a 's the ionization coefficients in the mixture, the N 's the concentrations (in gramme-molecules per litre) of the mixture with respect to the respective electrolytes, and the M 's the depressions produced by one gramme-molecule or one gramme-ion of the undissociated and dissociated portions respectively of the electrolytes. The a 's in this expression are given by the method to be tested; the m 's in the case of the electrolytes selected can have only one value; and the N 's are of course known; but what values the M 's are to be regarded as having is doubtful. It was found for simple solutions of the three electrolytes employed, that the molecular depressions increased as the solutions became more concentrated. This appears to indicate that one molecule or one ion, when in the presence of a large number of molecules and ions, produces a greater depression than when it is in the presence of a smaller number. Thus in the case of a solution made by mixing simple solutions of different electrolytes, since the number

of molecules and ions present seems to affect the power which one molecule or ion has of lowering the freezing-point, it was assumed that the depression produced by a molecule or an ion of say, the electrolyte 1, which is surrounded by molecules and ions of this electrolyte 1 and of the other electrolytes 2, 3, etc., would have the same value as if all the molecules and ions surrounding it were of electrolyte 1. Thus the M 's of the above expression have been regarded as equal to the molecular depressions in simple solutions of the concentration $N_1 + N_2 + \text{etc.}$

The application of this expression to the calculation of the depression in mixtures will form at once a test of the above assumption and a test of the ionization coefficients employed. I have applied it (*a*) to mixtures of potassium chloride and sodium chloride, these salts being selected because of their simple molecular structure and the approximate equality in their grade of ionization; (*b*) to mixtures of sodium chloride and hydrochloric acid, selected because of their simple molecular structure and the considerable difference in their grade of ionization; (*c*) to mixtures of potassium chloride, sodium chloride and hydrochloric acid, selected for testing in addition the method of finding the ionization coefficients in a mixture of three electrolytes.

The following is a synopsis of the work involved:—Purification of materials;—construction and calibration of the instruments used in the conductivity and freezing-point observations;—preparation and analysis of a series of simple solutions of the three electrolytes;—determination of the specific molecular conductivities at infinite dilution for 0°C. ;—observations on the conductivity at 0° for the series of simple solutions;—calculation of the ionization coefficients at 0° from the conductivity observations;—measurement of the depression of the freezing-point of the simple solutions;—calculation of the molecular depression for each solution of the three electrolytes;—preparation of mixtures of two and of the three electrolytes;—measurement of the depression of the freezing-point of the mixtures;—

determination of the ionization coefficients of the electrolytes in the mixtures;—calculation of the depression of the freezing-point in the mixtures.

The experiments were carried out during the session of 1899-1900 in Dalhousie College, Halifax.

Materials, Apparatus and Methods.

The salts and acids were obtained from Merck. The salts were recrystallized once, and it was found that solutions of them, and also of the acid, had conductivity values showing satisfactory agreement with the values as given by ¹Kohlrausch. These electrolytes were therefore considered sufficiently pure for the purpose. The water used in making the solutions was purified by the method described in my former ²paper, and it had a conductivity at 18°C. of about 0.95×10^{-6} expressed in terms of Kohlrausch's new ³unit ($\text{ohm}^{-1} \text{ cm.}^{-1}$).

The solutions of potassium and sodium chloride were prepared by direct weighing; the salts being first dried to constant weight in an air-bath. The hydrochloric acid solutions were analysed volumetrically by means of a standardized solution of potassium hydroxide with phenol-phthalein as indicator. All burettes and pipettes used in the preparation and analysis of these solutions were calibrated by the weight of distilled water they delivered, and the flasks by the weight of water they held at 0°C.

Observations were made on the specific gravity at 18°C. of the simple solutions and their mixtures with a pycnometer of the Ostwald-Sprengel form. These observations were made to obtain the knowledge whether or not there was any change of volume on mixing the simple solutions. It was found that with solutions of the concentrations used, there was no appreciable change, and it was assumed that such would also be the case at 0°.

¹ Kohlrausch u. Holborn : *Leitvermögen der Elektrolyte*, 1898, pp. 159, 160, tab. 2.

² *Trans. N. S. Inst. Sci.*, 10, 49, 1898-99.

³ Kohl. u. Holb., *loc. cit.*, p. 1.

Conductivities were determined by Kohlrausch's method with the alternating current and telephone. The Wheatstone's bridge consisted of four coils, two of which, the 100 and 1000 ohms, were the only ones used. These coils were correct at 17.5°C. and had a temperature coefficient of 0.000267 per centigrade degree per ohm. The correction for temperature was applied when the observations were made in the basement room referred to below. The platinoid bridge wire was calibrated by the method proposed by ¹Strouhal and Barus with ten german silver wires of equal length. A telephone made by Ericsson of Stockholm, and an inductorium made after a plan of Ostwald's and giving a clear high note were employed. For a detailed account of the pycnometer, and of the instruments employed in the conductivity observations, with the methods used, see my paper referred to above.

Three electrolytic cells of two types were used. One, with the shape of a U-tube, was employed for the stronger solutions of the hydrochloric acid. The other two were of the Arrhenius form. One of these, with electrodes at a distance from one another of about $\frac{1}{2}$ cm., was used for the weak solutions employed in the determination of the specific molecular conductivities for 0°C.; the other with electrodes at a distance of about 5 cm., for the stronger solutions of the two salts. The electrodes were all of stout platinum foil firmly fixed to the platinum wire and glass connections, so that the capacity of the cell once determined would remain the same throughout a series of experiments. These electrodes were platinized in a solution prepared from ²Lummer and Kurlbaum's recipe. The reduction factor of each of these cells, by which the observed conductivities were reduced to the standard employed by Kohlrausch, was obtained by comparing the values determined for two carefully prepared solutions of potassium chloride, with the values given by ³Kohlrausch for the same concentrations. Data for the

¹ Wied. Ann., 10, 326, 1880.

² Wied. Ann., 60, 315, 1897.

³ Kohl. u. Holb., *loc. cit.*, p. 159, tab. 2.

determination of the reduction factors were available only at 18° , but as the cell was of glass its value at 0° would not be practically different from that at 18° .

The water bath used in the observations of the conductivity at 18° was the same as that described in my former paper. In the case of the observations at 0° the bath was modified so that the temperature could be kept constant at 0° by means of pieces of ice floating in it, while the water was kept continually stirred. The ice was prevented from coming in contact with the cell by placing around the cell a cylindrical screen of wire gauze 17 cm. in diameter, and reaching to within 10 cm. of the bottom of the bath. By the addition or the removal of pieces of ice from the salt water, the temperature of the bath could easily be kept within one twenty-fifth of a degree for a sufficient time to make the measurement of conductivity. The observations were made in a basement room of the college, where the temperature, during the winter months, was generally below 6°C . The thermometer used was graduated to a fiftieth of a centigrade degree and its zero point was determined by the writer. Each solution was brought to about 0° before it was placed in the cell, and while in the cell successive observations of the conductivity were made to insure that the temperature of the bath had been taken.

The method employed for finding the freezing-point of the solutions was the same in principle as that proposed by ¹Loomis. The size of the protection bath was larger than that used by Loomis, and the stirring was done mechanically.

The thermometer used was of the Beckmann form. It was graduated to a hundredth of a degree, and could be read to a thousandth by aid of a small microscope, mounted on an upright stand. This thermometer was at a certain place on its stem firmly fixed in the cork of the inner freezing-tube (the freezing-tubes consisted of an inner and outer tube, the inner containing the solution whose freezing-point was measured) so that when in position its bulb was within 2 cm. of the bottom of the tube.

¹ Phys. Review, 1, 199, 1893 and 9, 257, 1897.

This inner freezing-tube was 28 cm. in length and 2.8 cm. in diameter and had its lower end re-entrant. The outer tube was 25 cm. in length and 3.15 cm. in diameter. The thickness of the glass being about 1 mm., there was an air space of about 1.5 mm. between the tubes. This space was found to be quite sufficient to prevent the formation of ice on the wall of the tube. The inner tube was supported in the outer by means of two rubber bands, one at the top and the other at the bottom. These bands also prevented the walls from touching one another. The length of the tubes allowed the solution to be well submerged in the protection bath and therefore almost freed it from the influence of the outside temperature.

In the determination of the freezing-point of a solution these tubes were surrounded by a mixture of salt water and pieces of ice, contained in a vessel of glass 35 cm. high and 11 cm. in diameter (called the protection bath). The cover for this vessel was one taken from the protection bath of a Beckmann apparatus. The glass of this vessel was $\frac{1}{2}$ cm. thick and was covered with asbestos paper that the effect of the temperature of the room might be lessened. It was found necessary to keep this bath at a constant temperature within a fiftieth of a degree, if values of the freezing-point agreeing with the mean value to less than a thousandth of a degree were desired. This was obtained by keeping the bath continually stirred. Any change of temperature was quickly recorded by means of a thermometer graduated to a fiftieth of a degree. The temperature of the bath could be raised by the addition of water at the temperature of the room, or lowered by the addition of pieces of ice, snow when obtainable being preferable.

The platinum stirrer for the freezing-tube was of the common ring shape, having wound around its ring a thin platinum wire, which would rub against the wall of the tube and thereby prevent the formation of an ice sheath. With constant stirring there was found no tendency for the ice to mass itself together and float to the surface, but it could be seen moving through the whole solution in tiny glistening particles. The stirrer for the

protection bath was of thick brass wire with two rings, one for the upper and the other for the lower portion. Both these stirrers were worked mechanically by means of one of Henrici's hot air motors placed at a distance of about 3 metres from the freezing-point apparatus. By means of a light belt this motor turned a small wooden wheel placed over the protection bath. A connecting-rod connected this wheel to a slider on a vertical guiding rod; and to this slider also were attached the two stirrers. Any range of stroke could be obtained by varying the distance of the connecting-rod from the centre of the wheel. As about 70 cc. of solution were used, a stroke of 11 cm. was required to cause the ring of the stirrer in the freezing-tube just to touch the bottom of the tube and reach to within $\frac{1}{2}$ cm. of the surface of the solution. Thus all solutions were throughout uniformly stirred, and as the stroke of the engine was quite constant every solution was stirred in exactly the same manner.

Another glass vessel of the same dimensions as the protection bath contained salt water and ice at a temperature of about -10°C . (called the freezing bath). The purpose of this bath was to reduce the solution in the freezing-tube to about 0.3 degree below the freezing-point.

The hammer of a common electric bell covered with a piece of rubber tubing, and supported on a frame over the freezing-point apparatus, was used for tapping the thermometer. A current from an Edison-Lalande cell had sufficient strength to give rapid and vigorous blows.

The following method of ¹ Raoult's was employed for determining the elevation above the temperature of the protection bath, of the convergence temperature of this apparatus, *i. e.*, the temperature finally assumed by a solution which is being stirred and has no ice in it, when it comes into thermal equilibrium with the protection bath. The freezing-point of water was first obtained. The ice formed in this observation was then melted and the freezing-tubes containing the water returned to the protection bath and the stirring begun. With the protection

¹ Ztschr. f. Phys. Chem., 27, 636, 1898.

bath kept constantly at 0° the temperature of the water in the freezing-tubes at first fell rapidly, then more slowly, till it remained constant at 0.05° . This experiment was repeated with the same result, and thus the convergence temperature was shown to be 0.05 degree above the temperature of the protection bath. In all experiments, therefore, the temperature of the protection bath was adjusted so as to be 0.05 degree below the freezing-point of the solution. It was also found with water that the protection bath required to be this same amount (0.05 degree) below the freezing-point in order that the value of the freezing-point, with a very small quantity of ice present, might agree with that obtained with a large amount of ice.

The method of carrying out an observation of the freezing-point was as follows:—The freezing-tube was filled with the solution up to a mark on the glass (about 70 cc.) It was then placed in the freezing bath where it remained till the temperature was lowered with constant stirring to about 0.3 degree below the freezing-point of the solution, this point having been determined by a preliminary experiment. The freezing-tubes were now quickly removed to the protection bath which was at the required temperature (0.05 degree below the freezing-point of the solution), and the stirring started. After ten minutes time, in which the solution had risen to within 0.1 degree of its freezing-point, a small crystal of ice was introduced through a glass tube in the cork. As the particles of ice gradually formed throughout the solution the mercury in the thermometer rose, and in about a minute assumed a fixed position. The tapping was begun and continued for half a minute when both it and the stirring were stopped, the microscope brought into position and a reading made. After again stirring and tapping, the thermometer was read again, this reading acting as a check upon the former. Care was taken to keep the protection bath constant at the required temperature throughout both these readings. The tubes were now removed, the ice melted, and the same operation repeated for a second observation.

As a change in the atmospheric pressure would cause a corresponding change in the thermometer, the freezing-point of the water used was determined about every three hours. The temperature of the room was kept as low and as constant as possible during the experiments, and no observation was made when it was above 5°C.

Since the freezing of my solutions was started about 0.1 degree below the freezing-point, the amount of ice formed was so small that the correction usually applied for the change in concentration, and, therefore, in the depression, comes within my limit of error. Thus the results are recorded without any correction.

Simple Solutions.

With the electrolytes K Cl, Na Cl, and H Cl, there is only one possible way for their molecules to dissociate, namely, into two ions. Hence expression (1) reduces to

$$M = \frac{\delta}{n(1+a)} \dots \dots \dots (3)$$

For the determination of the values of M , the other quantities, δ , n and a are obtained from observations on simple solutions; a being taken equal to the ratio of the specific molecular conductivity to the specific molecular conductivity at infinite dilution. As the solutions are at a temperature of about 0°C. in the determination of the freezing-point, the ionization coefficients should be obtained at approximately the same temperature. For this purpose measurements were made of the conductivity at 0°, both of solutions of the range of concentration used in the observations of the freezing-point and also of very dilute solutions of the electrolytes. These latter measurements are required for the determination of the specific molecular conductivities at infinite dilution for 0°C.

Determination of the Specific Molecular Conductivities at Infinite Dilution for 0°C.

A series of simple solutions varying in concentration from .01 to .0001 in the case of the salts, and from .01 to .001 for the

acid, were prepared and their conductivities measured at 18° and at 0°. The conductivity of the water used in the preparation of these solutions was measured at both temperatures, and its value subtracted in each case from the conductivity of the solution. Considerable care was required with these dilute solutions to obtain good results. The electrodes were thoroughly washed with a portion of the solution before placing them in the cell. Both the solutions and the water used were exposed as little as possible to the air, and the measurements were taken immediately after a solution was made. The measurements were repeated three times, and the mean of the values obtained was taken as the most probable value.

The following Table I gives the values thus obtained, and the ratio $\frac{\mu_{18} - \mu_0}{\mu_{18}}$, where μ_{18} and μ_0 are the specific molecular conductivities at 18° and 0° respectively. The concentrations are expressed in gramme-molecules per litre at 0°, and the specific molecular conductivities in terms of this unit and of 10^{-4} times Kohlrausch's new unit of conductivity.

TABLE I.

Concentration.	Sp. Mol. Cond. at 18°C. (μ_{18}).	Sp. Mol. Cond. at 0°C. (μ_0).	$\frac{\mu_{18} - \mu_0}{\mu_{18}}$.
K Cl. (74.59).			
.010	1224	775	.367
.005	1244	787	.367
.001	1278	809	.367
.0005	1284	814	.366
.0002	1293	821	.365
.0001	1298	824	.365
Na Cl. (58.50).			
.010	1028	638	.379
.005	1049	651	.380
.001	1075	664	.382
.0005	1084	670	.382
.0002	1094	676	.382
.0001	1098	679	.382
H Cl. (36.46).			
.010	3706	2595	.300
.005	3731	2608	.301
.002	3753	2625	.301
.001	3757	2626	.301

The ratio $\frac{\mu_{18} - \mu_0}{\mu_{18}}$ appears to increase as the concentration diminishes, except in the case of potassium chloride where it decreases. This peculiarity is also shown in the values as calculated by means of ¹Dégusne's data. The agreement between Dégusne's conductivity values at 0° and the above for the solutions of concentration .01 is very close, but with the dilute solutions it is not so good. It was found impossible to obtain

¹ Kohl. u. Holb., *loc. cit.*, p. 199, tab. 7.

concordant results with solutions of greater dilution than those above. It is seen, however, that the ratio appears to reach a constant value in these dilute solutions, and the writer has assumed that the value of this ratio for the solution of concentration .0001 of the salts and .001 of the acid would hold for infinite dilution.

Table II gives the values of the specific molecular conductivities at infinite dilution for 0° obtained from Kohlrausch's values at 18° by aid of the above ratios. The conductivities are expressed as in Table I.

TABLE II.

Electrolyte.	Specific Molecular Conductivity at Infinite Dilution.	
	For 18°C.	For 0°C.
K Cl.....	¹ 1312	833
Na Cl.....	¹ 1103	682
H Cl.....	² 3774	2638

Determination of the Ionization Coefficients at 0°C. for Simple Solutions.

For this purpose the specific conductivities at 0°C. for series of simple solutions of each electrolyte were found. These conductivity values are also necessary for the drawing of the curves showing the relation between the concentration and the conductivity; these curves being required in the determination of the ionization coefficients in the mixtures.

Table III contains the observed values and also the ionization coefficients calculated therewith. The concentrations are expressed in gramme-molecules per litre at 0°C., and the conductivity in terms of 10^{-4} times Kohlrausch's new unit.

¹ Kohl. u. Holb., *loc. cit.*, p. 200, tab. 8.

² Wied. Ann., 50, 385, 1893.

TABLE III.

Concentration. (<i>n</i>).	Specific Conductivity at 0°C. (<i>k</i>).	Ionization Coefficients at 0°C. (<i>a</i>).
K Cl.		
.03	22.73	.910
.05	37.15	.892
.08	58.32	.875
.10	71.83	.862
.20	138.5	.832
.30	204.5	.819
.40	268.1	.804
Na Cl.		
.03	18.34	.896
.05	29.92	.877
.08	46.93	.860
.10	58.03	.850
.20	111.2	.815
.30	161.0	.787
.40	208.9	.765
H Cl.		
.03	76.43	.966
.05	126.1	.956
.08	198.9	.942
.10	246.1	.933
.20	480.3	.910
.30	710.6	.898
.40	933.4	.884

Determination of the Values of M.

The following Table IV contains the values of the depression of the freezing-point of the simple solutions. These values, being the means of three observations, are given to four places of decimals. It also contains the values of the lowering (*M*) produced by each gramme-molecule or gramme-ion of the electrolyte

in the solution, calculated by expression (3) with the data given in this Table and in Table III. The concentrations are expressed as in former tables and the depressions in centigrade degrees.

TABLE IV.

Concentration. (<i>n</i>).	Depression of Freezing-point. (<i>d</i>).	Molecular Depression. (<i>M</i>).
K Cl.		
.03	.1060	1.85
.05	.1752	1.85
.08	.2776	1.85
.10	.3458	1.86
.20	.6795	1.86
.30	1.0171	1.86
.40	1.3487	1.87
Na Cl.		
.03	.1072	1.89
.05	.1768	1.88
.08	.2824	1.90
.10	.3515	1.90
.20	.6885	1.90
.30	1.0292	1.92
.40	1.3646	1.93
H Cl.		
.03	.1078	1.83
.05	.1786	1.83
.08	.2835	1.83
.10	.3552	1.84
.20	.7138	1.87
.40	1.4553	1.93

By comparing Loomis' values of the depression of the freezing-point with these values, it will be seen, that the agreement in many cases is very close. If both results are plotted the curve, formed by joining the points given by the above values,

will be a little above that obtained from Loomis' values. As mentioned above, the molecular depression increases as the solutions become stronger.

According to Van't Hoff's theory the value of the molecular depression should be 1.86. ¹Loomis found experimentally that, with a large number of non-electrolytes in aqueous solutions, the molecular depression was 1.86 for the dilute solutions. In the case of the electrolytes used above, with the ionization coefficients determined by the conductivity method, the values of the molecular depression are seen to be grouped around this value. The divergence from this value may partly be accounted for by the use of the doubtful values of the specific molecular conductivities at infinite dilution for 0°, employed in the calculations of the ionization coefficients.

Mixtures of Solutions of Two Electrolytes.

Since equal volumes of simple solutions of two electrolytes, having one ion in common, were mixed, and the molecules of the electrolytes used dissociate each into two ions, expression (2), as there was no change of volume on mixing, reduces to:

$$\Delta = \frac{1}{2} [M_1 n_1 (1 + \alpha_1) + M_2 n_2 (1 + \alpha_2)] \dots\dots\dots (4)$$

in which n_1 and n_2 are the concentrations of the simple constituent solutions. For the calculation of Δ the depression of the freezing-point of the mixture by this expression, the n 's are known, the α 's are obtained by the modification of Prof. MacGregor's method fully described in my former ² paper, and the M 's in the manner referred to above.

Results of the Calculations.

Table V gives the data necessary for the calculation of the depression of the freezing-point of mixtures of potassium chloride and sodium chloride, and of sodium chloride and hydrochloric acid. It also shows the agreement of the calculated with the observed values. The concentrations, molecular depressions of the constituent solutions, and the depressions of the freezing-points of the mixtures are expressed as in Table IV.

¹ Phys. Review, 9, 257, 1899.

² Trans. N. S. Inst. Sci, 10, 124, 1899-1900.

TABLE V.

Concentrations, Constituent Solutions at 0°C.		Ionization Coefficients in Mixture at 0°C.		Molecular Depression in Mixture.		Depression of Freezing-point of Mixture.		Difference.
K Cl. (a_1).	Na Cl. (a_2).	K Cl. (a_1).	Na Cl. (a_2).	K Cl. (M_1).	Na Cl. (M_2).	Observed Value.	Calculated Value.	
.05	.03	.902	.886	1.85	1.89	.1406	.1415	+.0009
"	.06	.890	.878	1.85	1.89	.1912	.1937	-.0005
"	.08	.883	.866	1.85	1.90	.2283	.2289	+.0006
"	.10	.878	.863	1.85	1.90	.2648	.2638	-.0010
"	.20	.854	.834	1.86	1.90	.4361	.4345	-.0016
"	.40	.829	.807	1.86	1.90	.7709	.7716	+.0007
.30	.03	.840	.825	1.86	1.90	.5661	.5655	-.0006
"	.06	.838	.820	1.86	1.90	.6164	.6167	+.0003
"	.08	.835	.818	1.86	1.90	.6519	.6501	-.0018
"	.10	.833	.816	1.86	1.90	.6856	.6840	-.0016
"	.20	.827	.798	1.86	1.91	.8546	.8531	-.0015
"	.40	.813	.775	1.87	1.93	1.1924	1.1937	+.0013

TABLE V—(Continued).

Concentrations, Constituent Solutions at 0°C.		Ionization Coefficients in Mixture at 0°C.		Molecular Depression in Mixture.		Depression of Freezing-point of Mixture.		Difference.
Na Cl. (n_1).	H Cl. (n_2).	Na Cl. (a_1).	H Cl. (a_2).	Na Cl. (M_1).	H Cl. (M_2).	Observed Value.	Calculated Value.	
.05	.03	.883	.960	1.89	1.83	.1436	.1428	-.0008
"	.05	.877	.958	1.89	1.83	.1786	.1783	-.0003
"	.08	.866	.952	1.90	1.83	.2307	.2315	+.0008
"	.10	.860	.947	1.90	1.83	.2654	.2665	+.0011
"	.20	.836	.924	1.90	1.85	.4438	.4432	-.0006
"	.40	.800	.908	1.91	1.88	.8057	.8034	-.0023
.30	.03	.825	.919	1.90	1.86	.5752	.5738	-.0014
"	.05	.824	.919	1.90	1.86	.6103	.6090	-.0013
"	.08	.820	.919	1.90	1.87	.6617	.6624	+.0007
"	.10	.815	.918	1.90	1.87	.6984	.6967	-.0017
"	.20	.797	.907	1.91	1.89	.8748	.8755	+.0007
"	.40	.770	.894	1.93	1.93	1.2450	1.2436	-.0014

It is difficult to estimate the limit of error of the above observations. The observed values are in all cases means of at least three observations, which were found to differ from their mean values in different cases by very different amounts up to 0.001 degree. There are also many sources of error in the calculations and they do not admit of exact valuation. As a rough estimate the limit of error due to both observation and calculation may probably be put at 0.0015 degree.

If this estimate is approximately correct, the above table shows that the agreement between the observed and calculated values is very satisfactory for both mixtures of potassium chloride and sodium chloride, and of sodium chloride and hydrochloric acid.

Mixtures of Solutions of Three Electrolytes.

In the case of mixtures of the three electrolytes used as equal volumes of the simple solutions were mixed, and there was no change of volume on mixing, and as each molecule of these electrolytes breaks down into two ions, expression (2) becomes

$$\Delta = \frac{1}{2} [M_1 n_1 (1 + a_1) + M_2 n_2 (1 + a_2) + M_3 n_3 (1 + a_3)] \dots (5)$$

where the n 's are the concentrations of the constituent solutions. Thus in any mixture the n 's are known, the M 's can be obtained as above, and the a 's can be determined by the method given below.

Determination of the Ionization Coefficients in Mixtures of Three Electrolytes.

¹ Professor MacGregor has shown how to obtain equations sufficient for finding the ionization coefficients in a mixture of any number of electrolytes having a common ion, and how to solve them by a graphical procedure. As in the case of mixtures of two electrolytes, ² I have, in the present case also, transformed

¹ Trans. Roy. Soc. Can. (2), 2, 69, 1896-97.

² Trans. N. S. Inst. Sci., 10, 124, 1899-1900.

Professor MacGregor's equations so as to express them in terms of regional conductivities and concentrations.

In the case of mixtures of three electrolytes the transformed equations are as follows :—

$$k_1 = \frac{\mu_{\infty 1}}{\mu_{\infty 2}} k_2 = \frac{\mu_{\infty 1}}{\mu_{\infty 3}} k_3, \dots \dots \dots (6)$$

$$\frac{N_1}{C_1} + \frac{N_2}{C_2} + \frac{N_3}{C_3} = 1, \dots \dots \dots (7)$$

$$\left. \begin{aligned} k_1 &= f_1(C_1), \\ k_2 &= f_2(C_2), \\ k_3 &= f_3(C_3), \end{aligned} \right\} \dots \dots \dots (8)$$

where 1, 2, and 3 denote the electrolytes, the k 's the specific conductivities of the electrolytes in the regions which they respectively occupy in the mixture, (these conductivities having the same values as in simple solutions of equal concentrations), the μ_{∞} 's the specific molecular conductivities at infinite dilution, the N 's the concentrations of the mixture with respect to each electrolyte, and the C 's the regional concentrations, which in the case of dilute solutions are the concentrations of the constituent isohydric solutions.

We have thus six equations for the determination of three k 's and three C 's.

These equations can be solved by a graphical process. In the first place the values of the specific conductivities of electrolyte 2, (k_2), are multiplied by the constant $\frac{\mu_{\infty 1}}{\mu_{\infty 2}}$, and those of electrolyte 3, (k_3), by $\frac{\mu_{\infty 1}}{\mu_{\infty 3}}$. Equations (8) are now employed by drawing curves having as abscissæ the values of the specific conductivities, and the corresponding values of the concentrations as ordinates. Three points are now found by inspection, one on each curve, having a common abscissa, according to equations (6),

and ordinates, (C_1 , C_2 and C_3), whose values when substituted in equation (7), satisfy this equation. By this method we have found k_1 , C_1 , C_2 and C_3 ; and k_2 and k_3 are easily obtained from equations (6). The α 's, the ionization coefficients in the mixture, are then determined from the relation, $\alpha = \frac{k}{\mu_\infty C}$.

Results of the Calculations.

The following Table VI contains the results of the calculations by expression (5); also the experimental values obtained for the depression of the freezing-point of mixtures of solutions of potassium chloride, sodium chloride and hydrochloric acid. The results in all the columns are expressed as in Table V.

TABLE VI.

Concentration, Constituent Solutions at 0°C.			Ionization Coefficients in Mixture at 0°C.			Molecular Depression in Mixture.			Depression of Freezing-point of Mixture.		Difference.
K Cl. (n_1).	Na Cl. (n_2).	H Cl. (n_3).	K Cl. (a_1).	Na Cl. (a_2).	H Cl. (a_3).	K Cl. (M_1).	Na Cl. (M_2).	H Cl. (M_3).	Observed Value.	Calculated Value.	
.05	.06	.05	.890	.874	.962	1.85	1.89	1.83	.1878	.1892	+ .0014
"	.10	.08	.875	.860	.944	1.85	1.90	1.83	.2712	.2705	- .0007
"	.20	.10	.853	.838	.931	1.86	1.90	1.85	.4070	.4094	+ .0024
.30	.08	.10	.840	.825	.919	1.86	1.90	1.86	.5515	.5537	+ .0022
"	.10	.20	.833	.814	.913	1.86	1.90	1.87	.6952	.6943	- .0009
"	.20	.30	.821	.790	.904	1.86	1.91	1.89	.9290	.9274	- .0016

The calculated values in this Table will have a greater possible error than those in Table V, due to the greater number of experimental data required. In the observed values the possible error is the same as before. Considering the many sources of error in both these values the above agreement between them is very satisfactory.

Conclusions.

The above results show that in the case of mixtures of solutions of potassium chloride and sodium chloride, and of sodium chloride and hydrochloric acid, and of all three, it is possible, with the ionization coefficients obtained by the method referred to above, and on the assumption that the molecular depression of an electrolyte in a mixture is the same as it would be in a simple solution of the same total concentration, to predict the depression of the freezing-point within the limit of the error involved in observation and calculation.

IV.—ON THE SUBDIVISIONS OF THE CARBONIFEROUS SYSTEM
IN EASTERN CANADA, WITH SPECIAL REFERENCE TO THE
POSITION OF THE UNION AND RIVERSDALE FORMATIONS
OF NOVA SCOTIA, REFERRED TO THE DEVONIAN SYSTEM
BY SOME CANADIAN GEOLOGISTS.—*By H. M. Ami, M. A.,
D. Sc., F. G. S., of the Geological Survey of Canada,
Ottawa.*

(Read December 11th, 1899.)

Considerable discussion has arisen of late amongst European as well as North American geologists, as to where certain series of sedimentary strata occurring near the summit of the Palæozoic should be placed, either in the Carboniferous or in the Devonian system.

Whether certain other geological formations, occurring in the Maritime Provinces of Canada, should be described as Permian, or classed as Upper Carboniferous or Permo-Carboniferous, constitutes another problem. It is not within the province of this paper, however, at this time, to discuss this latter question, which it is hoped may form the subject of another paper before long.

Where to draw the line between the Carboniferous and Devonian systems in Eastern Canada, is therefore the question at issue. It is the purpose of the writer to enter this field of enquiry without any leaning or bias to any one view, but to take up the evidence as it presents itself to him and as it was collected by him during the last four years in the Counties of Pictou, Colchester, Cumberland, Antigonish, Hants, and Kings, in Nova Scotia, referring to such other localities and additional evidence only as the occasion may require.

Numerous and varied opinions have been given by many writers on this important question of the dividing line between the Devonian and the Carboniferous. These were consulted merely with the purpose of obtaining notes of records of observations that might help to throw light upon the problem, without

any prejudice or desire to accept one view or another, unless the facts adduced proved to be wholly reliable evidence.

Abram Gesner, Sir William Dawson, Sir Charles Lyell, Dr. Jackson, Prof. Alger, Prof. J. P. Lesley, M. de Koninck, M. de Verneuil, Mr. Hugh Fletcher, Dr. R. W. Ellis, Mr. Henry S. Poole, Richard Brown, Prof. T. Rupert Jones, F. R. S., J. W. Kirkby, Mr. J. W. Salter, Dr. Henry Woodward, Dr. G. F. Matthew, Prof. Bailey, Mr. A. Smith Woodward, Mr. Robert Kidston, and Prof. David White, have all contributed by their writings, published or in manuscript, to the literature of this interesting controversy.

I shall not attempt to review the difference of opinion which may exist between what may be termed the two schools of geology as regards the constitution of the Devonian system, especially as regards the uppermost members of that system,—*The Lonsdalean School*, whose characteristics of the Devonian age are based more especially upon the life-zones or palæontological evidence which the formations hold, and *the Murchisonian School*, which emphasizes more especially the stratigraphical succession, with little reference to palæontological evidence.

From a considerable study of the origin or genesis of the various geological formations in question, or of the cycles of constructive forms affecting them, the periods of erosion noticed, together with the life-zones which these formations contain, and characterize them, one has been able to arrive at a conclusion which, it is hoped, will be in accord with the views of the rest of the world, so that whatever interpretation is given to the Carboniferous system in one continent, the same should likewise hold good for another. The same with the Devonian system.

Just as Time was a constant factor during the evolution or history of the Carboniferous system of this world, and that the amount of time involved is a definite period, so also was Life a constant factor; and the several subdivisions of the Carboniferous system—the Eo-, Meso-, and Neo-Carboniferous, must be marked by corresponding series of Life-zones of the same system.

No difficulty has been experienced in separating the various geological formations in the Counties of Nova Scotia mentioned above, nor of understanding their taxonomic relations. The most excellent work of Mr. Hugh Fletcher, of the Geological Survey of Canada, who kindly furnished me with maps and plans of the region in question, shows clearly the true and natural order of sequence of the formations. The main question at issue, however, has been where to place the series of sediments hitherto known, and designated by Mr. Hugh Fletcher as the "Rocks of Union and Riversdale": in the Carboniferous or in the Devonian system. Mr. Fletcher would place them in the Devonian. I include them as formations in the Carboniferous system (and would also classify in the same system the red rocks of Mispec and the Lancaster fern-ledges of New Brunswick, which hold much the same flora and fauna). The various formations of the Carboniferous system do not form an unbroken succession of sedimentary strata in the disputed region either of Pictou, Colchester and adjacent counties. Great breaks and unconformities appear on every hand.

It may not be considered out of place here to look for a moment at some of the principles involved in such questions as arise in this problem. Portions of formations constituting cycles of sedimentation or of constructive forms, marking peculiar physical conditions of deposition, followed by periods of erosion, and subsequent depositions, occur at various horizons, and were it not for their entombed faunas it would be most difficult to state in which of the subdivisions of the Palæozoic column to place them. Where sedimentation as marked by cycles of constructive forms is not continuous, the basis or principle upon which the separation of the different members of the series depends, must obtain in the palæontological evidence collected in the various members whose succession, though not perfect, is, nevertheless, known as to its order.

Similarity in the types or organic forms found, assists one in uniting series of sediments as part and parcel of one system, just as dissimilarity enables one to separate series of sediments from

which they were derived. Comparisons must be instituted between the various life-zones occurring in the natural succession of strata, and wherever they are exposed they can easily be recognized however fragmentary or isolated they may be, provided they are fossiliferous, and that the evidence thus obtained can be compared with standard sections recognized the world over. The characteristic life-zones of the Carboniferous System, as they have been elaborated the world over, can be very easily prepared, and in order to be recognized as typical they must be in accord with the concensus of opinion with the rest of the world. They must not contain assemblages of organisms or types which are not in harmony with, but must be organically and chronologically related to, the types that are everywhere held to be of Carboniferous age. Fortunately for the geologist, although there are unconformities or breaks in the succession of strata there is abundant evidence of life of various orders and classes entombed in the various formations.

THE JOGGINS SECTION.

One grand and continuous section of strata of the Carboniferous system to very near the summit thereof, in which are entombed myriads of organisms, plants and animals in regular succession also, is found along the Joggins shore, in the western portion of Cumberland County, Nova Scotia. This section was described in detail by Sir William Logan, and subsequently by Sir William Dawson and Dr. R. W. Ells. It extends from Minudie to McCarren's Cove, along the shore of the Cumberland Basin. This forms one standard section. No other such exists in Nova Scotia, and a systematic collection of the fossil organic remains entombed in its strata ought to be made for reference, in order to compare the succession of life-zones here with those of other portions of Nova Scotia and North America. In the United States, Mr. David White informs me that there have been noted not less than seven standard sections of the Carboniferous System, in distinct fields: Pennsylvania, Virginia, Ohio, Missouri and other States. These all have their peculiar charac-

ters, and may be described as local series. Whereas each particular basin of Carboniferous rocks or sediments may have its own particular conditions of sedimentation which led to peculiar local differences existing between the several basins which may be under examination and comparison, there can be no doubt at all about the series belonging to the Carboniferous System, when the results obtained in Great Britain, France, Germany, and the world over, have been consulted.

Such a recognized succession as the consensus of opinion in the world has established as marking the Carboniferous System, must be a term which includes within its scope the various members of the different local series under examination.

Unequal amounts of sedimentation at different horizons in a System and in different districts, have created difficulties, but formed an interesting feature in the study of the correlation of strata. It has been conceded that in the case of the 14,000 feet of strata which constitute the Joggins section in Nova Scotia, sedimentation must have been very rapid, and though deposited in a perfectly unbroken succession, such strata may have taken much less time actually to be laid down than a few hundred feet of shales and sandstone belonging to the same system in another section.

It follows from this, that local series of Carboniferous strata may be of very great thickness in one part of the continent, or comparatively thin in another part. It is possible for the whole system of the Carboniferous to be unusually extensive in its development of sediments, as has certainly been the case in Nova Scotia when compared with sediments of the same age in Pennsylvania. There is evidence of great rapidity in sedimentation. Evidence of rapidity in sedimentation is clearly seen in the strata, what I refer to the Eo-Carboniferous of Colchester and Pictou Counties in Nova Scotia, as represented by the Union and Riversdale formations. Ripple-marked surfaces and shallow water indications occur on all sides. Hundreds of feet of unbroken succession of strata, practically each stratum beautifully marked by ripples and wind action, as well as by the foot-

prints and trails of reptilian and other animals, such as are seen to occur at East and West Bay, near Partridge Island, Parrsboro, and point clearly to rapid deposition or accumulation of sediment along a fast-sinking floor.

The main reason for introducing this argument is to combat the view advanced in certain quarters, that by placing the Union and Riversdale formations into the Carboniferous system, it would make the latter too cumbersome and unwieldy a system, and take away from an older, underlying system—the Devonian, and rob it of parts of its sediments. The following occur to me to constitute the successive series or sediments which belong to the Carboniferous system in certain portions of Nova Scotia.

I.—THE EO-CARBONIFEROUS.

In this lower portion of the Carboniferous system, I would place the Union and Riversdale series of sediments, which are well and extensively developed in Pictou, Colchester and Cumberland Counties; at Union and Riversdale; along Harrington River; on the Moose River; at East and West Bay, near Parrsboro; Archibald's Brook; Oliver's Mills; McKay's, etc., on the East River of Pictou, and at numerous other localities.

The expressions "Rocks of Union and of Riversdale," I would describe as formations, calling one the Union formation, the other, the Riversdale formation. These are easily recognized over wide areas, geographically, and are characterised by a well-defined fauna and flora, at least as far as the Riversdale formation is concerned, the Union formation owing to its highly ferruginous character proving almost everywhere to be very destitute of fossil organic remains.

FOSSILS FROM THE RIVERSDALE FORMATION.

The two principal localities from which the fossils of this formation may best be obtained, occur in the Riversdale Station district, close to the boundary line between Colchester and Pictou Counties, and in the Harrington River district near the boundary between Colchester and Cumberland Counties.

Riversdale District.—Fossils from this locality were obtained along the Black River branch of the Salmon River, along the Calvary Brook, just east of Riversdale; also in the numerous cuttings along the line of the Intercolonial Railway between West River Station (Pictou County) and Riversdale Station (Colchester County).

In the rather fine grained dark gray or greenish gray arenaceous and black or dark carbonaceous shales of the cuttings along the I. C. R., plants, as well as animal remains, occur. Amongst the groups of organic remains examined and reported upon up to date are a series of plants sent to Mr. Robert Kidston of Stirling, Scotland. The entomostraca were submitted to Prof. T. Rupert Jones, F. R. S., and the crustacea (Podophthal-mata) to Dr. Henry Woodward.

PLANTÆ.

1. *Arterophyllites acicularis*, Dawson, (= *Calamocladus equisetiformis*, Schl.)
2. *Sphenopteris marginata*, Dawson.
3. *Neuropteris*, sp.
4. *Alethopteris*, sp.; allied to *Alethopteris valida*, Boulay.
5. *Cordaites principalis*, Germar.
6. " *Robbii*, Dawson.
7. *Cyclopteris* (*Nephropteris*) *varia*, Dawson.
8. *Calamites*, sp. (?)
9. *Cardiocarpum cornutum*, Dawson.

CRUSTACEA, (Xiphosura).

Belinuridæ.

1. *Belinurus grandævus*, Henry Woodward and T. R. Jones.

CRUSTACEA, (Entomostraca).

Phyllopoda.

1. *Leaia tricarinata*, Meek and Worthen.
2. *Leaia Leidyi*, var. *Bæntschiana*, Beyrich and Geinitz.
3. *Estheria Dawsoni*, Jones.

LAMELLIBRANCHIATA.

1. *Anthiacomya elongata*, Dawson.
2. " *obtusa*, Dawson.

Insecta.

1. "A neuropteroid insect allied to *Miamia Bronsoni*"—determined by Prof. Charles Brongniart, of the Muséum d'histoire Naturelle, Paris, France.

Vermes.

1. *Spirorbis Eriaia*, Dawson, attached to leaves of *Cordiaites Robbii*, Dawson.

Harrington River District.—The shales and sandstones, from which the fossils of the Riversdale formation were obtained, occur along the boundary of the counties of Colchester and Cumberland—the strike of the strata being generally across the direction of the stream. As pointed out by Mr. H. Fletcher, this locality proved to be particularly rich in fossils.

PLANTÆ.

1. *Arterophyllites acicularis*, Dawson.
2. *Calamites*, sp.
3. *Sphenopteris dilatata*, Dawson.
4. " *Harttii*, Dawson.
5. " *splendens*, Dawson.
6. " *marginata*, Dawson.
7. " sp.
8. *Aneimites valida*, Dawson.
9. *Adiantites* ? or *Archæopteris*, sp.
10. *Neuropteris*, sp.
11. *Alethopteris discrepans*, Dawson, (= *Alethopteris decurrens*, Artis, sp.)
12. *Cyperites*-like leaves.
13. *Cardiocarpum cornutum*, Dawson.
14. *Psilophytum* ? *glabrum*, Dawson.

Animalia.

BATRACHIA.

1. *Hylopus Logani*, Dawson.

2. *Sauropus Dawsoni*, (M. S.)—From rocks apparently of this age which occur at East Bay near West Bay and Partridge Island, two miles below Parrsboro.

LAMELLIBRANCHIATA.

1. *Anthracomya elongata*, Dawson.
2. " *obtusa*, Dawson.

CRUSTACEA.

1. *Leaia tricarinata*, Meek and Worthen.
2. *Carbonia*, sp.
3. *Estheria Dawsoni*, Jones.
4. *Anthracopalæmon*? n. sp.

The Riversdale formation thus carries a flora and fauna, which cannot be taken as one appertaining to any other system than the Carboniferous, inasmuch as the types are all akin, and generally conceded to be closely related, even to types in the productive coal measures higher up in the system.

I have no hesitation to state that, in the Union and Riversdale formations, we have obtained in Nova Scotia a fauna and flora, which, while not as extensive nor as varied as that obtained in the productive coal measures of the same Province, are nevertheless remarkably similar in their biological characteristics, imbedded in a series of sediments, terrigenous in character, and for the most part estuarine, carrying Carbonaceous shales and sandstones, underclays and conglomerates, constituting just a series of strata as that, which, having begun in Eo-Carboniferous time, were interrupted by an encroachment of the Carboniferous Sea (Windsor formation) in which marine conditions prevailed, and limestones were deposited, holding abundance of marine shells and other fossil organic remains peculiar to salt-water conditions, and were followed by newer, or higher, or later strata, such as are met in the "Millstone grit" and "Coal measures" of the same region, of various writers, characterised also by terrigenous deposits, and enclosing a fauna and flora whose affinities are remarkably akin to the forms found in the Eo-Carboniferous

formations of Union and Riversdale, giving us the following natural, though interrupted general succession of strata, in descending order :—

SUCCESION.	CONDITIONS.	FOSSILS.
III. Coal Measures and Millstone grit.	Estuarine.	Land plants, land animals, shallow water conditions and forms.
II. Windsor formation.	Marine.	Marine shells, corals, sea-life.
I. Union and Riversdale formations.	Estuarine.	Land plants, land animals, shallow water conditions and forms.

As evidence of the similarity of forms peculiar to the Eo-Carboniferous of Colchester and Pictou Counties and the Coal measures of the same, let us take the different orders or groups of fossil organic remains affording Palæontological evidence as noted on page 181 of the "Summary Report of the Geological Survey Department for 1898 and 1899."

EVIDENCE FROM ANIMAL LIFE.

Insecta.—Neuropterous insects have been discovered in the shallow water deposits of Riversdale age, in a cutting on the Intercolonial Railway east of Riversdale and Campbell's Siding, about a mile and a half west of West River Station, and the *wing* obtained and sent to the Museum d'Histoire Naturelles, is referred to a Carboniferous genus by Prof. Brongniart, of Paris, France—a most eminent authority on the Fossil Insects of the Carboniferous.

Phyllopora.—The numerous specimens of *Leaia* and *Estheria* from the Carbonaceous and other shales of the Riversdale formation of Colchester, Pictou, and Cumberland Counties, are very similar to the forms described from the Coal Measures of Pictou, County, and also from the Coal Measures of the United States. All the species of *Leaia* recorded in North America so far, are

referred to the Coal Measures. This genus, however, was abundant in early Carboniferous times, as may be gathered from those specimens obtained by me in the red, black and gray shales of the Union and Riversdale formations of Nova Scotia, which, though they underlie the Marine limestones of the Windsor formation, are nevertheless referred to the Eo-Carboniferous, a position which the enclosed fauna of Phyllopods warrants in assigning.

Crustacea.—Several specimens of a new genus, and new species of one of the Podophthalmata and Xiphosura, occur in the Harrington River and Riversdale collections in Colchester County. These Crustaceans are highly characteristic of the Carboniferous system in Europe and America, and their occurrence at this horizon, together with their generic characters, point to them as prototypes of higher forms found in the higher subsequent cycle of sedimentation in the series of sediments referred to in the Coal measures above. Of these, *Belinurus grandævus*, T. R. Jones and H. Woodward, has been recently described, and the authors describe it as a Carboniferous form, related to Carboniferous species in Great Britain.

Amphibia.—Of these animals there are both footprints and trails in the collection of the Geological Survey or National Museum at Ottawa, which are referable to the genera *Sauropus* and *Hylopus*, which were obtained from rocks of Union and Riversdale horizon, and some are of gigantic size. All other footprints referable to this genus in North America, have been described as Carboniferous and, consequently, the Parrsboro and Spencer's Island specimens are Carboniferous, rather than any other horizon.

In his "Geology, Chemical, Physical and Stratigraphical," Oxford, 1888, Professor Prestwich gives a table "Showing the character and distribution of the species of organic remains in the several main groups of the Palæozoic series in the British area." Under the head of Amphibians (including footprints) he notes the occurrence of these in the Carboniferous, but none in the Devonian.

Dr. S. A. Miller, in his "North American Geology and Palæontology," containing that useful Catalogue of North American Palæozoic Fossils, does not record a single Amphibian from rocks older than the Carboniferous, and the genera *Sauropus* and *Hylopus* occurring in the Riversdale formation of Nova Scotia, are identical with and similar to those found in the Carboniferous, or other regions of North America.

Prof. James D. Dana, in his "Manual of Geology," Sir Archibald Geikie in his "Text Book of Geology," also, all the leading nomenclators and writers on North American or European Geology and Palæontology, agree in placing the genera *Sauropus* and *Hylopus* to which I have referred the footprints from Parrsboro and Harrington River, of Cumberland and Colchester County, from the Riversdale formation, as Carboniferous.

Lamellibranchiata.—Of these the most conspicuous are the *Anthracomyæ* of Salter, which Sir William Dawson described under the name of *Naiadites*. These shells are abundant in the Coal Measures of the Joggins, Springhill, Pictou and Sydney Basins of Nova Scotia, also in the Pennsylvania, Virginia and other coal areas of the United States, not to speak of their occurrence in the Carboniferous of England and France, and many other countries of Europe. They occur in bands in the Riversdale formation at Riversdale, and in numerous outcrops along the banks of the Harrington River, on the dividing line between Colchester and Cumberland Counties, and the term "*Naiadites Bands*" or "*Naiadites Shales*," which are usually associated with *Ostracoda* of the genus *Carbonia*, and other allied genera of Carboniferous affinity, is applicable to these Eo-Carboniferous bands. All writers on Geology and Palæontology, concur in placing these shells in the Carboniferous. All the species recorded from the United States are referred to the Coal Measures, whilst those from the Union and Riversdale formations of Colchester and Cumberland Counties in Nova Scotia, are, by the writer, placed in the Eo-Carboniferous. It will thus be seen that the palæontological evidence adduced in the geological collections so far obtained from the Riversdale formation of Nova Scotia,

including Insects, Phyllopods, Crustaceans, Amphibians and Lamellibranchiata, are all types which are markedly akin to types well known to occur in the Carboniferous of other countries, and more than that, such are usually met with in the Coal Measures of the same.*

It has been one of my constant endeavours to obtain Devonian fossils from those areas of Nova Scotia ascribed to the Devonian in the Riversdale and Harrington River Sections; but I have found only Carboniferous types.

EVIDENCE FROM PLANT LIFE.

Besides the above, there is the evidence adduced from the flora collected in the strata which yielded the forms of animal life just cited above, and it can be truly said that it also has a decided Carboniferous facies. The genera *Asterophyllites*, *Sphenopteris*, *Alethopteris*, *Cardiopteris*, *Stigmaria*, *Calamites*, *Poacites*, *Cordaites* are all represented. From communications recently received from Mr. Robert Kidston, of Stirling, Scotland, the well-known author of the British Museum Catalogue of Carboniferous Plants, who has examined the forms sent him, we learn that he is satisfied that the flora is truly a Carboniferous one.

Quite independently, Prof. David White of the Smithsonian Institution and United States Geological Survey at Washington, arrived at the same conclusion when he kindly made a preliminary examination of the collections from Nova Scotia cited above, and then in our possession at Ottawa, and invariably referred the forms detected to the Carboniferous system.

From our own study of the numerous collections obtained in the so-called disputed areas in question, from the areas of the Riversdale formation, we cannot but come to the conclusion that instead of finding Devonian types of plants and animals, they proved in almost every case to be Carboniferous. Neither is it to be wondered at, that, on studying the affinities and relations of the fossil plants, etc., of Riversdale, McKay's Head, and Har-

* The term "Coal Measures" is an unfortunate one to designate a Geological formation, and should never be used to designate horizon. It is a purely lithological or economic term, and conveys no idea of the Geological position in the Time scale. Productive Coal Measures can occur at any horizon in the Carboniferous.

ington River, from strata now referred to the Riversdale formation, Sir William Dawson placed them in the Millstone Grit formation, so intimate are their relations to the plants of the Coal Measures; and from my own observations also to the faunas and floras which are now known to immediately underlie the Millstone Grit of certain portions of Nova Scotia.

The Riversdale formation must now, therefore, both on account of its position in the succession of sediments and especially from the life-zones it holds, be classed as an Eo-Carboniferous formation. This formation clearly underlies that series of marine limestones referable to the Windsor formation, as this has been described and mapped out fully by Sir Wm. Dawson, and more lately and with special care and accuracy by Mr. Hugh Fletcher.

II.—THE MARINE SEDIMENTS.

In the districts of Nova Scotia under examination, besides the Eo-Carboniferous formations of Union and Rivesdale, consisting of red shales and sandstones and conglomerates, more or less strongly cemented together, together with the series of dark grey coloured, and black or greenish and rusty shales as defined by Mr. Hugh Fletcher, forming a great thickness of sediments, constitute one of the cycles of sedimentation peculiar to the Carboniferous System, there occur certain other strata overlying these unconformably, viz.: the marine limestones and associated gypsum, marls, shales and sandstones.

These marine limestones, &c., hold abundance of fossil organic remains, as shown on the East Branch of the East River of Pictou at Springville; at Brookfield; and Miller's Lime Kiln near the D. A. R. Bridge, Windsor, N. S., where the series is highly fossiliferous and the forms are well preserved. The term, "Windsor Series," is quite applicable to these strata and deserves to be recognized as constituting a typical formation or phase of the Carboniferous system in this portion of Eastern Canada.

Just where to place this *Windsor formation* in the column of Palæozoic formations has not yet been definitely ascertained. Whether it is to be classed as one of the Eo-Carboniferous sediments, or whether it constitutes a factor or part of what may be termed, according to Prof. H. S. Williams's very appropriate classification, Meso-Carboniferous, is the question occupying our mind at present. It is, nevertheless, to be remarked that the fauna it contains is one in which so far not one of the Uppermost Devonian fossils of the Gaspé and other regions of Eastern Canada have been detected.

The occurrence of this formation in certain basins of Nova Scotia marks a cessation of the conditions existing in the areas which these limestones cover, showing that the sea or Atlantic waters in Carboniferous times extended over the Eo-carboniferous deposits previously laid down, which had been subjected to subsidence and erosion previous to their being overlaid, whilst the vegetation and climate did not, probably, change very materially in the high land during this period of submergence and encroachment of the sea. A period of elevation evidently must have followed the deposition of the limestones, marls, &c., and sandstones and mudstones and shales were deposited, to be followed later again by sandstones with shales and coal seams peculiar to the "Coal Measures" and "Millstone Grit" formations.

Such deposits are essentially terrigenous as to their origin and the structure, as well as origin and mode of deposition of the Coal Measures need not be described. The flora and fauna they hold mark the estuarine conditions existing and prevailing at the time, also the luxuriant growth of plants on land with the contemporaneous animal life of the period both in the water and on the land also.

A brief summary of the succession of the sediments in the Carboniferous of Nova Scotia in Pictou, Colchester and Cumberland counties in part, such as the writer has observed it in numerous outcrops and localities, gives the following section in ascending order:—

1. *Riversdale and Union formations*: Consisting of red

sandstones and conglomerates, carbonaceous shales and mudstones, besides diorites and other basic intrusive rocks.

2. An unconformity.

3. Windsor limestones and Hopewell sandstones, constituting distinct formations which overlie the Union and Riversdale formations.

4. (An unconformity, according to Mr. Fletcher.) I have not yet been able to detect any unconformity at this juncture. There is no unconformity between the Millstone grit and the underlying shales, calcareous and other conglomerates and sandstones of Cumberland Basin.

5. Millstone grit of Skinner McDonald's Brook.

6. In certain portions of Pictou County, N. S., an unconformity occurs, *e. g.*, at Blackwood Brook, opposite New Glasgow, where the upturned edges of the "Millstone Grit" (Logan) are overlaid by the New Glasgow conglomerate of Fraser's Mountain, &c., whereas in other portions the Millstone grit is directly superimposed by the Coal Measures, *e. g.*, at Westville and the Joggins.

This peculiar geological succession in these two areas give us two series of sediments in the succession of formations which in part only are synchronous, hold similar organic remains, but exhibit great variety in sedimentation.

A. *Joggins and Westville Areas.* B. *New Glasgow Region.*

V. Millstone grit. V. Millstone grit.

VI. Coal Measures.* VI. Unconformity (of Blackwood Brook).

VII. New Glasgow conglomerate.

VIII. Spirorbis limestone.

IX. Smelt Brook shales and sandstones.

X. Pictou sandstones.

XI. Cape John formation, red sandstones and conglomerate.

* The Coal Measures of Pictou County at Stellarton and Westville consisting of bituminous shales, clays and sandstones, are not anywhere seen to be overlaid by any of the formations in series B.

We would thus have the following tentative TABLE OF FORMATIONS in the Carboniferous of part of Nova Scotia:—

FORMATIONS.	Northern Areas.	Southern Areas.	Order.
NEO-CAR- BONIFEROUS	{ Cape John.....	{ Cape John Sandstones.....	XII.
	{ Pictou.....	{ Pictou Freestones.....	XI.
	{ Smelt Brook....	{ Smelt Brook shales.....	X.
	{ Small's Brook..	{ Spirorbis limestones.....	IX.
	{ New Glasgow ..	{ N.Glasgow conglomerates.....	VIII.
		Coal Measures..	VII.
	Unconformity.		
MESO-CAR- BONIFEROUS	{ Stellarton.....	{ Millstone grit	VI.
	{ Westville	{ Unconformity (?).....	V.
	{ Hopewell.....	{ Hopewell and	IV.
	{ Windsor.....	{ Windsor.....	III.
	Unconformity.		II.
EO-CAR- BONIFEROUS	{ Union	{ Union	I.
	{ Riversdale	{ Riversdale.....	

NOTE.—It is not at all improbable that the Smelt Brook formation (IX.) overlying the New Glasgow (conglomerate) formation is equivalent to the Stellarton (VI.) or "Coal Measures" formation, which would indicate clearly the existence, as in other portions of the palæozoic in Eastern America, of two distinct series of formations which are nevertheless synchronous. The writer hopes shortly to describe each of the formations indicated in the above tentative Table of Formations for a portion of Nova Scotia, together with the relations of the latter to other palæozoic sediments in the same and adjoining Province of New Brunswick.

V.—THE NATURAL HISTORY OF MONEY, BY PROF. J. DAVIDSON,
PHIL. D., *Fredericton, N. B.*

(Read May 14th, 1900).

It is hardly possible to determine whether there ever was a time in the history of the race when each individual was self-sufficient, and, like the Homeric Cyclops, paid no regard to others. Some of the Australian tribes are so low in the scale of civilization that even barter is unknown amongst them, but whether these represent the universal primitive type cannot be determined one way or the other. It is evident, however, wherever we find the first germs of social life, we find, at the same time, a kind of rude division of labor which necessitates, and renders possible, the beginnings of trade. Trade in its origin is simply barter, the direct exchange of one article for another. But barter, however simple in appearance, is more complicated than modern exchange. It must often have happened in the early history of trade that two parties failed to make a trade for the simple reason that, while both were anxious to give what they had, in exchange for what they wanted, neither of them needed or desired what the other had to offer. This lack of coincidence has frequently placed travellers in very great straits. If the native who holds the store of food does not find in articles which the explorer displays to catch the aboriginal fancy, something which attracts him, he passes on, and the traveller and his party have to go hungry. Sir R. Burton warns the would-be explorer against assuming that any sort of trinkets will suffice for the purchase of supplies and the hiring of labor. The African native has his own standard of taste, and no matter how gaudy and how gimcrack the stock of Brummagem goods displayed may be, the native will take such things only as agree with his standard of taste. Nothing will induce the primitive savage to take what he does not immediately require in exchange for the food the traveller desires,

unless the articles offered in exchange conform to his standard of taste.

The inconveniences of this primitive state of barter are so evident that no race or tribe which has made the first step away from barbarism, can for long remain without some sort of medium of exchange. There is need of some commodity which will be readily received by every one, although at the moment he may not wish to consume it, in the full assurance that he can easily, in his turn, exchange it for the article he does desire. Such an interposed commodity will greatly facilitate exchanges, and to all intents and purposes may be regarded as money. What this interposed commodity is depends almost entirely on circumstances. At first, almost any commodity which is esteemed by everybody in the community will serve the purpose. There is no more foundation for the idea that there was a sort of social contract regarding some one article to be used as a medium of exchange than there is for the other historical fiction that law and language are due to a primitive contract or convention. No one article has been adopted as if by natural right. The original medium of exchange was simply a marketable article with a recognized value. Metallic money has reached its present supremacy because in the struggle for existence it has demonstrated its superiority. There is no natural desire for the precious metals; and even for gold there does not seem to be any natural and inherent desire apart from its utility. The *sacra fames auri* is a fiction of the poet and a description of the civilized mind; and the first discover of a gold nugget possibly viewed it as a sort of substitute for a bead or a shell for a necklace. Even to this day, there are peoples who do not esteem gold, and will give nothing for it. The various British and Egyptian Soudan expeditions were compelled to take along with them bulky Maria Theresa dollars, because the Arab would not take gold in exchange. The taste of the Arab is for silver ornaments. He is no fanatical silver man desirous of seeing silver remonetised. Gold he could not, or at least was not accustomed to, use as ornaments for his person, his horse, or his

weapons. Hence, gold had little utility for him, and the transport service was burdened with large quantities of bulky Austrian silver dollars. There are certain qualities which civilized communities require in the medium of exchange; but in early commerce these were not always demanded, perhaps often not even thought of. Each community has selected the commodity which best suits its conditions, and in the course of progress each has adopted and in time abandoned many kinds of money. But whatever the nature of the medium of exchange adopted, it served as money; and it is justly entitled to be called money, even although not metallic, or not coined; for, after all, as Prof. Walker says, "Money is that money does." For the needs of modern trade, primitive money materials are entirely unsuited; but they serve their own purpose, and as in the eyes of an early missionary to the Mexicans who, contemplating the bags of cocoanuts used by the Aztecs, exclaimed, "Blessed money! which exempts its possessors from avarice since it can not be long hoarded or hidden under ground," primitive money may have peculiar advantages of its own!

When in any district or community any particular commodity comes into general use, and is readily available, it generally comes in time to be unit of value and the medium of exchange. Its nature will, of course, depend on the climate and geographical position of the district; and may be changed when the community advances to another stage of culture. The natural medium of exchange may be altered, even although the community has made no such advance. When a primitive community comes into commercial contact with a more advanced race, an entirely new medium of exchange may be adopted. Thus, gin and gunpowder are, according to Bishop Tugwell, of Uganda, to all intents and purposes, the only currency in certain parts of Africa. The foreign trader may create a new value by his demand for produce which hitherto has been little esteemed. In the Caroline Islands stone money in the form of quartz wheels, varying from six inches to twelve in diameter, was formerly the money the natives used; but since the advent of

the white trader bags of copra or dried cocoanut kernel have come into general use.* The usual effect of such a contact of races has been the substitution of a corresponding manufactured article for the original commodity used by the natives. Thus, among the Pacific Coast Indians, blankets have become the medium of exchange in place of furs. Since all exchange is mutual, the civilized trader must abandon his natural medium of exchange and adopt the medium of exchange prescribed by the character of the trade. Thus, in the New England colonies, wampum, a form of shell money, and in French Canada, beaver skins, were used naturally in the trade with the Indians at all times; and on occasion, owing to the scarcity in the colonies of small change, these articles were used as money between Europeans. Indeed, in many communities where money, as we know it, is, for one reason or other, scarce, commodities may come into use as money, not because the people know no better, but because they have no better. Thus, on the north-east coast of Newfoundland at this day, cod alone is currency.†

The natural currency of a community is that commodity in which its wealth mainly consists. In the hunting stage of society property consists in weapons of war and the chase, in a few simple, natural ornaments made of shells or teeth, and in the skins of animals, which serve for clothing, and for the covering of the hut or wigwam. But as man advances in civilization, he succeeds in taming animals, whose flesh and milk form his foods, whose skins or wool form his clothing. This is the pastoral stage in which a man's wealth is reckoned by his herds. In the more settled agricultural stage, property consists not only of slaves and domesticated animals, but of dwellings and grain, and above all, of stocks of the precious and other metals, though indeed, in early history, all metals are precious. These later forms of wealth man has come to value according to his earlier standards of wealth; and there is every reason to believe that the original standards of value of metallic coins are based on mere primitive ox and cow units. When man has come into

*F. W. Christian. *Geographical Journal*, Feb., 1899.

†Lant: Cruising on the French shore *Westminster Review*, March, 1899.

the possession of the metals, and has acquired the power of working them, a long course of monetary development is possible for him. He finds out by experience which metal suits his purpose best; and that purpose may change as the centuries pass. Our present currencies are the result of the law of the survival of the fittest. The primitive condition was general use; and that always remains the first condition of the use of an article as currency. But along with that, there are other conditions which are stated in every monetary text-book. All the metals have been used in turn. Iron was used in Sparta, and is used to-day in the Dark Continent. Lead and tin, and platinum, gold, and silver, and copper, have all been used. But experience has shown that gold and silver pre-eminently, and copper, or some alloy of it, in a less degree, are best suited for currency purposes.

This has been the general course of development; but though it is sometimes hard, amid all the talk about progress to realize that the stationary state of society is the usual phenomenon, yet it is true that most peoples have not become civilized, and since many remain in the most primitive stages of society, we still have many actual instances of primitive currency in present day use. Progress seems alike impossible in the frozen north and in the torrid south; and in these regions the conditions of life are almost unchanged, and there we may see the kinds of money our forefathers of untold generations ago employed.

The rigour of the northern winters prevents the rearing of domestic animals, or the systematic cultivation of the soil, and there the primitive hunting stage still exists. The wealth of these Arctic communities consists in skins, and in some cases of dried fish, which they exchange with the trader from the south for their few luxuries or use for their own clothing and sustenance. Under these conditions skins, or their modern equivalents, form the natural medium of exchange. A writer in a popular magazine gives a graphic description of the skin money used in the Hudson Bay Territories:

"In old times, when an Indian wanted a rifle, the rifle was stood on end, and the Indian laid furs flat on the ground till

they were heaped to the top of the gun barrel ; then the Indian took the rifle, worth possibly \$50, and the Hudson Bay Company took the furs, worth from \$100 to \$1000, the large variation being due to the absense of discrimination on the part of the Indian

“At the Hudson’s Bay Company posts, on the Mackenzie River, actual money is unknown ; all trade being conducted by means of a curious imaginary currency, the unit of value of which is ‘one skin.’ What sort of skin ? No one knows ; in fact it is no sort of skin in particular. It is merely an imaginary skin, about equivalent in value to half a dollar. The hide of a beaver is worth ten skins ; a musk ox hide is worth thirty skins ; a fine silver fox hide is worth 300 skins. These are the big bills of this unique currency.

“Small change is made by musk rat hides, worth one-tenth of a skin ; by mink hides worth two skins, and by lynx hides worth four skins. A wolverine hide is worth sixteen skins. There is a fluctuation in the value of this currency just as there is a fluctuation in the value of silver, consequent upon the increase or decrease in its production.”*

But skin currency is not so unique as this writer imagines it to be. We have no modern instance so complete, but we have many traces of the same practice. In Northern Asia the skin of the Siberian squirrel was and is the monetary unit ; and etymology shows that many of the northern nations were in the same position. “In the Esthonian language the word *rûtra* generally signifies money, but its equivalent in the kindred Lappish tongue has not yet altogether lost the original meaning of skin or fur.”† And the name of a Russian small coin, the $\frac{1}{4}$ kopeck, is said to mean half a hare skin, showing that the Muscovites had originally a skin currency—a fact which is also established‡ by the circulation of leather money in Russia as late as Peter the Great. Even in regions where there were possibilities of development, the earliest money was of this

*Lee Merrithew : “Cosmopolitan,” Nov., 1899.

†Jevons : Money and the Mechanism of Exchange, p. 20.

‡Ridgeway : Origin of Currency and Weight Standards, p. 13.

character. "Skin for skin, yea, all that a man hath will he give for his life," is a text we generally understand in some obtuse way to mean a reference to a man's own skin. What it really points to is that, even in the pastoral stage of society which the book of Job describes, skins were the standard of value; and classical writers record the traditions that the earliest currency used in Rome, Sparta, and Carthage, was formed of leather. Sir John Mandeville, or his unacknowledged authority, tells us that in China, when he visited it, leather money was in circulation.

We find what seems a still more modern instance in the fact that Saint Louis, the great king of France, finding a great scarcity of silver coin wherewith to pay his soldiers, caused pieces of silver wire to be fixed on leather and so circulated. But this was rather a device for protecting the silver than an actual leather money. The silver gave the value, and the leather served only as a case to preserve the small piece of silver (9 or 18 grs.) from being lost.

In some communities, particularly those brought into closer contact with the traders of advanced race, the blanket of the trader has supplanted the original skin currency. This has taken place in some parts of the Hudson Bay Company's territory and eleewhere. Along the British Columbia coast also the Indians use blankets as the unit of exchange. The blankets are distinguished by prints or marks on the edge woven into the texture, the best being four-point, the smallest and poorest one point. The unit of value in trade is a single two-and-a-half point blanket, worth about a dollar and a half. All commodities are exchanged according to this standard; even the four-point blanket is said to be worth so many blankets.*

In the case of these Indians the development may have been due to a growing scarcity of fur bearing animals, and perhaps from the same reason, and also from natural development, we find in Scandinavia, in Iceland, and in the Orkney Islands,

*Dawson: Report on the Queen Charlotte Islands. Geol. Survey Report of Canada, 1880.

that cloth was the standard. Wadmail, or coarse woollen cloth formed the basis of an elaborate system of currency in Norway.*

In Iceland this cloth currency gave place with the development of trade to a currency of stockfish. The foreign traders did not desire the northern coarse cloth; but there was a steady market in Southern Europe for fish. There is extant a proclamation for the regulation of trade between England and Iceland in which an elaborate scale of prices for articles of all kinds is drawn up in terms of dried codfish.† And in Newfoundland cod was for a long time, and still is in many parts, the only coin.

In general, one may say that whenever there arises a scarcity of metallic money in a community which produces one chief article for trade, that article will serve as money. Thus cod was used in Newfoundland, tobacco in Virginia, wheat and maple sugar in Nova Scotia,‡ tenpenny nails, as Adam Smith tells us, in Kirkaldy, olive oil in the Levant, tea in Central Asia, block salt in Abyssinia, and in various parts of Asia and Africa.

The history of the currency experiments of the European colonies in North America is instructive. These communities suffered from a chronic want of coin, one of the results of an ill-considered colonial policy. Tobacco was a form of currency in Virginia sanctioned, not only by custom, but by actual legislation. In 1619, the first General Assembly of the colony established a ratio between tobacco and silver; and almost every succeeding Assembly dealt with the same question. In 1642, tobacco became the sole legal tender; and it was not till 1656 that silver could again be used if required. But tobacco remained the actual medium of exchange, and in 1730 paper money, like our modern grain receipts and pig iron warrants, was issued against tobacco. These, along with the commodity, formed the main money in Virginia down to the beginning of the present century, and were preferred, because more stable in value, to the continental currency. In the New England colonies a very great variety of articles of trade was made legal tender.

*Morris and Bax: *Socialism, its Growth and Outcome*, p. 249 n.

†Ridgeway: *op. cit.*, pp. 18, 19.

‡Patterson: *Memoir of the Rev. James MacGregor, D. D.*, p. 82.

Beaver skins formed the greater part of the circulating medium, and in 1631 it was enacted that grain could be paid unless beaver or money (that is metallic money) were called for by the contract. This law remained in force for half a century ; and other agricultural commodities were added to the list as occasion seemed to demand. Corn, wheat, barley, and peas, at fixed prices per bushel, were sanctioned by law as currency, and taxes could be paid in them at the discretion of the taxpayer.*

A similar colonial policy produced similar results in French Canada. The scarcity of metallic money was even greater than in the English colonies ; and at all times commodity substitutes for metallic coinage were in use. The scarcity was so great that in addition to the beaver skin, which was practically the unit of value, wheat was declared a legal tender in 1669 at four livres the mint, while in 1673 the council further ordered that bear skins could be tendered in payment at their current value.†

But to return to the monetary practice of primitive communities. In the torrid zone clothing is a burden, and nature supplies plenteous store of the food suited to the climate. The chief objects of desire are ornaments. The instinct for personal adornment is one of the most powerful instincts of the race. Shells were the earliest and simplest articles so employed ; and we find shell money used in all parts of the world. In the torrid zone they still form the principal medium of exchange. The cowries of the countries round the Indian Ocean have many of the qualities which we require in the money material. They are durable, portable, and are universally esteemed. In India and Siam, in West Africa, as well as in East Africa, and indeed at one time or another in every country in the world on whose shores they are found, cowries serve as the small change of commerce. They are to-day collected in vast quantities in the Maldive and Laccadive islands to be exported to serve as money elsewhere. The value fluctuates enormously, depending on their abundance or scarcity. In Africa traders estimate a

*White: Money and Banking, Chap. 1.

†Kingsford: History of Canada, Vol. 1, p. 156.

thousand shells at a shilling, while in India 5000 represent a rupee. The area over which they circulate is very large; and we have evidence that they were at one time used in countries which have long since abandoned them. The familiar Chinese cash, which are estimated by the string, is at least part proof that shell money, which is usually strung for convenience sake, was once the currency of the Celestial Empire, although the cash itself is a survivor, not of this shell money, but of an original knife money of which we shall hear later. The money of the Solomon Islands consists of neatly worked pieces of shell about the size of a shirt button. These are strung on strings about four yards long, and are distinguished under the names of white and red money. In the Caroline Islands shell money circulates, not as shells, but as real money, without immediate reference to adornment. The shells are chipped all round till they form disks quarter of an inch in diameter, and then are smoothed down with sand and pumice. The porcelain money of China, and perhaps the clay tablets of Assyria and the seals of Egypt, may be perhaps regarded as more developed forms of the same kind of money. In other places shells of other sorts were used. In early China perhaps, also, among the early Greeks, tortoise shell was used, and in China to this day the phrase tortoise shell is still used to indicate money.*

The wampum of America is another instance of shell currency. It consisted of black and white shells polished and fashioned into beads, and then strung in necklaces, etc. Black ones were twice as valuable as white. Wampum was so well established as currency among the Indians that it was made legal tender among the settlers, not that white men valued it as ornament, but because it was in constant demand by the natives and also because there was a scarcity of small coin. The unit of wampum money was the fathom consisting of three hundred and sixty white beads, and was worth about sixty pence. At first wampum was legal tender only to the extent of 12 pence, or the limit of the legal tender of bronze coin to-day. But in

*Ridgeway : op. cit., p. 21.

1641, owing to a greater scarcity of coin, wampum was made legal tender up to £10, though in 1643 the limit was reduced to £2. The decline of the beaver trade drove it out of circulation. When it could no longer be exchanged in large amounts for beaver skins, an article of international trade, the basis of its value was gone, although its use was continued in the frontier districts well down into the eighteenth century.*

Shell money is still used by North American Indians. The tribes of California, according to Mr. Powers, make use for money not only of the red scalps of woodpeckers, but also "of the dentalium shell, of which they grind off the top and string it on strings; the shortest pieces are worth twenty-five cents, the longest about two dollars, the value rising rapidly with the length. The strings are usually about as long as a man's arm." When these Indians became familiar with the silver coinage of the United States, the use to which they put the dimes and quarters shows how the new money, as well as the old, derived its value as a medium of exchange, because it was prized as an adornment of the person. "Some of the young bloods array their Dulcineas for the dance with lavish adornments, hanging on their dress 30, 40, or 50 dollars worth of dimes, quarter dollars, and half dollars, arranged in strings."† The same aboriginal instinct appears sometimes among semi-civilized aldermen. The Bowery saloon, which was paved with silver dollars, used to be, and perhaps still is, one of the sights of New York; and it would not have been inappropriate had Silver Dollar Smith, the owner, been a member of Tammany, which in the day of its political power, still tricks its members out in paint and feathers on gala days and sends them down Third Avenue under their Sachems, brandishing tobacco store tomahawks.

Other articles which have been desired for purposes of ornament have also been used as money. The Californian Indians use not only shells, but the red scalps of woodpeckers for their

*White: Money and Banking, Chap. 1.

†Quoted Ridgeway, op. cit., p. 15. Conversely solid brass buttons with the eye hammered flat were extensively used half a century ago in St. John, New Brunswick, for small change.

greater units of value. In Fiji, whales' teeth were used instead of shells, and white teeth were exchanged for red teeth somewhat in the ratio of shillings to sovereigns.* In Africa ivory tusks, and in the Solomon Islands dog teeth, which are worn in necklaces, express the higher values, while shells are used for the smaller. The currency of the Solomon Islands includes many different articles, and the value of each relatively to the others is carefully determined. The currency table, as set forth by Mr. Cook,† is :

10 cocoanuts	= 1 string of white money.
10 strings of white money	= 1 string of red money, or
	= 1 dog tooth.
10 strings of red money	= 1 string dolphins' teeth.
10 strings of dolphins' teeth	= 1 fine woman.
1 mable ring (for ornament)	= 1 good hog or 1 useful young man.

When man becomes a worker in metals, the primitive shell ornaments are replaced by gold and copper, and silver; and much of the money used in Africa to-day is of this character.

But man is a creature of customs, and the forms of his necklaces did not change to utilize the peculiar characteristics of the new materials. Nuggets of native gold may have been here and there threaded on a string; but there is little doubt that man's first attempt in metal working consisted in imitating the old shell ornaments, and in imitating those shell ornaments which had come to be used as money. In Siam there are silver coins in the shape of shells; and in China we have a copper coin known as a Dragon's eye, which was fashioned in the shape of a cowry. But long before the precious metals were coined, they were in circulation by weight, as they still are in the East. The commonest form in which the metals circulated was in the

*Jevons: Money, p. 25.

†For these details regarding the Solomon Islands, I am indebted to a note in an issue of the "Popular Science Monthly," which I cannot find again. In the same note it is said that rope ends, ornamented with red feathers, to be worn about the waist, are also used as money.

shape of ornaments; and some writers have spoken familiarly of ring money as if it were really stamped and coined money such as we use to-day. In reality, the so-called ring money was an article of barter, circulating by weight. The ancient ring money of Egypt, and of the early Celts and Teutons, is represented in Africa to-day by the coin currency of Calabar, and the rod currency of the Congo region, these being simply brass or copper wire, soft enough to be bent into the rings and bracelets, and other ornaments in which the African black takes delight.

When man advances to the pastoral stage, which he has done, and apparently can do, only in the temperate climes in which cattle can live, we find him estimating his wealth in cattle; and naturally the medium of exchange adopted by such societies is that which all desire, and all in a measure possess. Most of the civilized nations have long since left their cattle currencies centuries behind; but still in their language and archæological remains, in their literatures and their religious customs, there survive traces of the days when cattle formed their standard of value and their medium of exchange. "It is very possible that kine were first exclusively valued for their flesh and milk; but it is clear that in very early times a distinct and special importance belonged to them as the instrument or medium of exchange."*

The Latin term "*pecunia*" is derived from "*pecus*," a herd; the English "*fee*" is from the Anglo-Saxon "*feoh*," which survives in the cognate German from *Vieh* cattle; and rupee is said to be derived from the Sanskrit *rupa*, which also means cattle; and in the Book of Job the word *Késitch* (= a lamb) is employed to signify a piece of money.†

The veneration in which the cow is held in modern India by a people to whom the eating of beef is an abomination, is held by some to point back to the ages when the ancestors of these people in some more northern region had a great respect for

*Maine: The Early History of Institutions, p. 149.

†Wilkinson; The Ancient Egyptians, Vol. II., p. 151.

cattle as forming the principal item in their wealth. And although every shepherd was an abomination to the Egyptians (Genesis, c. 46, v. 34), as Joseph instructed his brethren, yet the Egyptians worshipped their great divinity Apis under the form of a bull, and worshipped also a sacred ram; customs which probably show that at some time or other their ancestors, whether in the northern Soudan or in Asia, and still in the pastoral stage, had regarded with proper veneration the cattle and the sheep which constituted their wealth.

The earliest literatures both of Aryans and of Semites show that cattle were wealth, and the measure of wealth and the medium of exchange. The wealth of the Patriarchs was measured by their flocks and herds, and we need only refer, in the almost equally familiar stories in Homer, to the one-sided exchange between Glaucón and Diomedé "of golden arms for brazen, those worth one hundred oxen for those worth nine." When history opens, most of the nations which afterwards played leading parts were still in the pastoral stage. Egypt had already passed beyond it, and the Greeks were making the transition to the agricultural and settled conditions of life. And as each nation first demands our notice whether in the Mediterranean region, in northern Europe, or in Central Asia, it is almost always the same picture that is presented of a pastoral people whose wealth consists in flocks and herds. And not only have we *a priori* reason to suppose that the chief item of their wealth formed their rudimentary medium of exchange; but we know from literature and from archæology that the ox was their unit of value. We have scales of value preserved to us in the Sacred Books of the East; and of these scales we have what might be almost exact transcripts among the semi-civilized tribes of the Caucasus and Central Asia, and of Northern and Southern Africa at the present day. The earliest coins of Greece which have been discovered are stamped with the head of an ox; and the legal code of Draco retains with true legal conservatism the otherwise obsolete practice of expressing values in terms of oxen. Indeed there is more than probability, there

is proof as strong as the nature of the subject permits, that our present system of metallic coins are translations of the earlier cattle currency. The Greek talent of gold and the ox were undoubtedly equivalent; and the ox is of course the older standard of the two; and the small change of this commodity currency was likewise translated into corresponding silver and copper coins. We find the same equating, the presence of which we partly detect and partly infer in the Greek world, going on to-day among peoples which are just passing from the pastoral to the settled mode of life.

When this change takes place man generally has some rudimentary knowledge of metallurgy; and the agricultural products have not often formed a unit of value. We have local instances and temporary instances; but these are by no means confined to the beginnings of the agricultural stage. They appear in colonial history almost as frequently as in semi-barbarous societies; and are generally due, then and now, to a scarcity of precious metals. Wheat has some advantages as a standard of value over the precious metals, as those colleges at Oxford and Cambridge know to their advantage who were restricted in the reign of Elizabeth to corn rents; but as a medium of exchange agricultural produce has such obvious disadvantages that no people which was able to use the precious metals has ever systematically used grain and other produce of the earth.

The metals are so much better suited than any other commodities to serve as the medium of exchange that it was inevitable that they should rapidly supplant all other forms of currency, so soon as gold and silver and the others had come to possess the fundamental requisite in a medium of exchange, viz., that it should be an article in general use and demand. But the metals came but slowly to possess this fundamental requisite; and we are certainly not justified in assuming that metallic currency superseded all others as soon as man had discovered the means of mining and working the metals. On the contrary, it is certain that the older currencies remained in circulation long

after man had acquired the necessary metallurgical knowledge. In the Homeric poems we have evidence of the concurrent use of definite weights of gold and silver, and iron, with the older ox unit.

The metals acquire value as all other articles acquire value, because they are suited to satisfy certain human needs. After the metals have been adopted as money, they acquire a distinct and special importance because of their utility as the medium of exchange; but first of all they must acquire the direct value that arises from direct utility. The metals are valued by man chiefly as ornaments, or as the material out of which the implements of industry or the weapons of war may be fashioned. The precious metals are valued for their utility as ornaments only. Neither gold nor silver had been put to serious use either in war or in industry. They obtained their value because of their attractiveness as ornaments for adorning the person, and in all probability the earliest form in which gold circulated was in strings of nuggets or beads resembling the older shell necklaces. Ancient geographers tell us that in Arabia native nuggets were used as ornaments. "Having perforated these they pass a thread of flax through them in alternation with transparent stones and make themselves chains, and put them round their necks and wrists."* But with increasing knowledge of how to work the metals, gold dust, as well as "fireless gold," as these Arabian natives called it, was fashioned into ornaments, and at first, no doubt, after the older models. Primitive coins are in existence, and in some cases still in circulation, in which the evolution from the ring and shell can be traced.

As man's chief employment in the early stages of society was war and the chase, weapons of war were greatly prized and jealously guarded. Consequently we find many traces of the employment of the implements of war as a medium of exchange. Even in the stone age we know that this was the case. Tough green stone slabs, valuable for making hatchets, form the unit of value among the lowest Australian natives who have hardly yet

*Strabo and Diodorus Siculus, quoted Ridgeway, *op. cit.*, pp. 75-77.

advanced far enough to carry on trade by means of barter.* Weapons formed part of the currency of Homeric times and among the ancient Norsemen. By the laws of Hakon the Good penalties for breaches of the law could be paid among other things in weapons.† Gunpowder competes with gin in the battle of the African standards introduced by European traders; and, not long since, an English newspaper, in commenting on a petition of a philanthropic committee that some other form of currency than that of gin should be adopted in the Delta of the Niger, suggested more than half seriously that Lord Salisbury should use his influence with the concert of Europe "to make the Liverpool powder keg the only legal tender in the gin latitudes." Among all the aboriginal tribes which have been brought into contact with European traders, the musket quietly takes its place in the native standard of value. But in Borneo they have gone a step further. A brass cannon, or as it is called by the natives, a brass gun, is the standard of value, and in all parts of the island one may still hear prices reckoned in brass guns. Any one who has transactions of such importance, for the brass guns will correspond to our larger notes, will instantly translate the sum into dollars at the present day; but there was a time when ten or twenty pounders did actually pass from hand to hand.‡

In more recent times, and if not among ourselves, at least among the ancestors of many of us, bullets have circulated as small change. Leaden bullets were legal tender in the New England; and the reason was no doubt partly the atmosphere of warfare and danger in which the early colonists lived. But there was another reason. The want of small coin in the reign of Queen Elizabeth had induced tradesmen and others to issue token money; and in consequence there was great distress often among the poorer classes for the issuer not infrequently refused

*Tyler: *Anthropology*, p. 281.

†Ridgeway: *op. cit.*, p. 35.

‡This fact is on the authority of an undated second-hand clipping from the "London Standard."

to honor these tokens. Accordingly, in the reign of James I., the striking of copper farthings was made a monopoly, and in the spirit of the times given to a court favorite, Lord John Harrington, who took unreasonable advantage of his opportunities. The circulation was encouraged in various ways with disastrous results to the commerce of the country. But not content with the fraudulent profits made at the expense of the commerce of the country, he caused large parcels to be shipped to the colonies. The Pilgrim Fathers, however, would have none of them; and it stands in the records of Massachusetts on "March 4th, 1634, at the General Court at New Town, brass (or copper) fathings were forbidden, and bullets were made to pass for farthings."

But the useful metals could also be put to the more fruitful use of serving as implements of industry, where their superiority over stone and wood is no less obvious than when they are fashioned into weapons of war. In Africa, which, owing to the absence of native copper, never had a bronze age, but passed at once into the iron age, we find still in full force the systems of currency which have either completely disappeared, or have left but indistinct traces elsewhere. There we find hoe money and axe money in practically their original forms. Iron in its natural state was a means of exchange in the Homeric age, and the iron money of Sparta was probably traditional in origin, like the Hindu reverence for the cow. But in Africa to-day iron is an almost universal medium of exchange. On the west coast the bar is the unit; and all things are reckoned in "bars" pretty much as they are reckoned in blankets among the Pacific Coast Indians. Originally the bar was what its name denotes, a bar of iron of fixed dimensions, one of the chief articles of trade between the natives and the early European traders. Now it has a conventional value, which, in Sierra Leone, is two shillings and threepence. In Central Africa, among the Madis, according to Dr. Felkin, "the nearest approach to money is seen in the flat round pieces of iron which are of different sizes . . . They are much employed in exchange. This is the form in

which they are kept and used as money, but they are intended to be divided into two, heated and made into hoes. . . . Ready made hoes are not often used in barter. Iron, as above mentioned, is preferred, and is taken to the blacksmith to be fashioned according to the owner's requirements."* But in Darfur the actual hoe serves as currency. "It is simply a plate of iron fitted with a socket. A handle is fitted into this socket and one has an implement suited for chopping the weeds in the corn fields. Purchases of small value are made with the hoe from one to twenty,"† which may be said to be its legal tender limit. Larger purchases are made by means of cotton cloth and oxen. Among the wild tribes of Annam, in Asia, also, the hoe serves as currency, and in ancient times many nations seem to have used it. We know that the Chinese had originally a barter currency of real hoes and real knives, articles in great demand among them. These in time became conventionalised in form, and were reduced in size to serve as real money. The Chinese cash is the survival of the original knife money, while the hoe, in a certain form, still circulates in Thibet, as it did in China hundreds of years ago. Within recent years the Thibetans have adopted the Indian rupee; but have not preserved its integral form. They cut it up for purposes of small change into little pieces which represent the conventionalized form of their own original hoe currency.

The hoe served as a general article of barter because of its indispensability in agriculture; but among fishermen the fish-hook was a more useful and desirable implement. Among the fishermen of the Persian Gulf, and round the coast to Ceylon and the Maldivé Islands, there was originally a fish-hook currency; and when true money was adopted the old form was retained. Down till the beginning of the present century *larins*, a bent piece of silver wire, the conventionalized form of the fish-hook, were in circulation; and it is possible that, had the natural process of evolution gone on without interference from

*Quoted Ridgeway, op. cit., p. 43.

†Ridgeway, op. cit., p. 45.

the outside, in course of time the piece of double wire would have become a bullet-shaped piece of metal, just as the bullet coins of Siam struck in European fashion represent the last stage of the original ring currency of that country.*

At one time axes served as money in many countries. At first it was the actual implement or weapon itself; but in time a conventionalized form was adopted. In West Africa to-day almost the sole currency in many districts has the form of an axe. These are too small now to be actually used, either as weapons of war or as implements of industry; but the shape has been preserved unchanged, and it is evident that the days are not long past when a currency of actual axes was employed.

We have evidence from archæology and from literature of a similar usage among the Greeks. There seems to be little ground for doubting that the earliest coins were imitations in metal of the older article which the metallic currency replaced. Thus, the coins of many Greek states and cities bear on their faces evidence of the nature of the commodity currency they replaced. When the coins were for circulation among a purely Greek people, there could be no difficulty in passing at once from the commodity to a piece of metal stamped with the image of the article whose value the coin represented. For instance, the Greeks of Cyzicus stamped their coins with the image of a tunny fish which was probably a part of their commodity currency at an earlier date; and these coins are, in most respects, like modern coins. But, in Olbia, a Greek colony on the Black Sea, where the Greeks traded with the barbarians, and the population moreover was of mixed race, the tunny fish was also the chief article of trade. There it was found necessary to make a concession to the lower level of intelligence of those with whom they traded, and perhaps also of many of their own citizens; and consequently a coin in the actual shape of a tunny fish was struck to represent the probable original commodity currency. In the same way the axe appears on the coins of

*Del Mar: *A History of Money in Ancient Countries*, p. 109.

Tenedos, and there is more than probability that just as the tunny fish coin of Cyzicus represented the earlier form so the axe stamped coins of Tenedos represented an earlier axe currency. We know from the *Iliad* that axes were given along with oxen, slaves, kettles, etc., as prizes in the funeral games for Patroclus. "But he (Achilles) set for the archers dark iron, and he set down ten axes and ten half axes," *Iliad* XXIII., ll. 850-1; where the half axe is obviously the single headed axe. The earliest coins of the Island of Tenedos, which lies off the Troad, bear the device of the double headed axe and represent an original axe currency such as we find in Africa to-day.

While the ox undoubtedly formed the unit of value and a medium of exchange over the whole of the wide area from the Straits of Dover to the Himalayas, as indeed in every other region where it can flourish, it was nowhere the sole medium of exchange. In almost every region of which we have any information, there is, or was, a regular scale of value in which the ox was simply the chief unit. Some writers have tried to show that the ox was unsuited for currency purposes, because it was incapable, without the adoption of the Scythian practice of cutting steaks from the flanks of the living animal, or the Celtic practice of bleeding the cattle to make the unleavened bread more nutritious, of sub-division to transact the smaller exchanges; and that their use must quickly on that account have been abandoned. Cattle were unsuitable in many ways, though they had considerable stability and uniformity of value throughout their continental range; but the reason their use as money was given up was not their lack of divisibility, for, as we have said, they never formed more than the principal article in a carefully constructed scale of exchange values.

To this day in the Soudan we find, that while the ox is almost universally the standard of value and the medium of exchange for more valuable articles, each particular district has its own peculiar lower units, generally selected from the articles most in

*For this and the other instances from the Greek coinage which follow, and for many others from which these are selected, see Ridgeway, *op. cit.*, Ch. XII.

demand in the district, or from those which the district has special facilities for producing. In one place it is sticks of salt, in another tobacco, in another cotton thread, in another raw cotton in the pod, in another onions, in another hoes, in another copper rings, beads, shells, etc., and in most districts more than one of them. These are for small change, so to speak. But all of them are recognized submultiples of the standard unit, the ox, as our quarters and ten cent pieces are of the dollar; and in the same way, slaves are in many districts there now, as they were in Homeric times, the larger currency, being recognized multiples of the standard ox.

From Greek coins which have been preserved, it is inferred that the Greeks had the same system. There are traces of it not only in Homer, but on the silver coins themselves. With the introduction of metallic currency, the Greeks equaled the ox with the gold talent, while its submultiples were represented by corresponding silver coins. At first, at least, these silver coins often bore as their stamp the representation of the commodity currency with which they were equaled and which they displaced. In many cases no doubt the image and superscription were religious; but there is no reasonable ground for doubting that in their origin many, perhaps all, of these coins bore on their face the evidence of the particular commodity they had displaced as currency. In some cases the representation was carried so far that the coin reproduced the actual shape of the commodity; and even where the stamp on the coin is of a religious character, there is a striking resemblance between the stamp and the article for which the district was famous. In many cases this correspondence is so clear that it is impossible otherwise to explain the peculiar form and image of the coin.

Thasos, for instance, was famous for its wine; and the wine cup or measure appears on its early coins. The unit of capacity, in the case of wine was the measure, and the measure is stamped on the coins to express the fact that this silver coin, bore the same relation to the gold talent as the actual measure of wine

bore to the original ox unit with which the gold talent had been equaled. The olive, again, was the most important product of Attica, and was probably, as it still actually is in many of the countries bordering on the Mediterranean, whether in the shape of olives or of olive oil, an actual medium of exchange; and the silver coins of Attica which replaced this olive currency most appropriately bore the olive sprig. The cuttle fish was an esteemed dainty by the Greeks, as it is to this day in Naples, and also along the Levant; and the coins of Croton bore its image. The ear of wheat appears on the coins of Metaportum, which grew wealthy because of the agricultural resources of Magna Græcia.

Before the invention or discovery of the art of pottery, man made use of natural shells, and many of the Greek names for earthenware vessels are the names of sea shells. Even after earthenware and wood had replaced these primitive and natural utensils, vessels were fashioned, as can be seen in the museums of antiquities to-day, in the old shapes. Thus there are Greek vases in the British Museum which reproduce the shape of the tortoise, and in the South Sea Islands to this day the natives imitate the tortoise shell in wood and earthenware. The tortoise shell was always specially valued, and in China it was used, and perhaps is still used, to make bowls of great beauty. It is to be expected that we should find, as we do, the tortoise shell standing at the top of the ancient Chinese scale of values. Among the Greeks and other Mediterranean peoples it was also valued; and it was the principal article with which the citizens of Aegina carried on their trade with the Phœnicians. It naturally, therefore, was a unit in their scale, and when the shell and commodity currency was replaced among them, as among the other Greek peoples, by silver coins, they stamped their silver coin with the image of the tortoise. And they took pains to make the coin actually represent the tortoise, for it has a high round upper side with a flat under side and markings to indicate the shell. The scarabs of Egypt, pieces of baked clay or porcelain, cut or moulded in the shape of beetles and tortoises, were in all proba-

bility used as money and represent an earlier shell, probably tortoise shell currency.*

In time the mercantile significance of these symbols was forgotten, and a religious interpretation placed on them. But even in the peculiar deities of a district we may often trace the history of its early commerce; and the religious symbolism of the later coins does not contradict the mercantile significance of the images on the early ones. Early peoples, and later ones, very easily discover grandiose explanations for what in their origin are commonplace facts. To take but one instance. The famous iron money of Sparta, which, according to tradition, Lycurgus caused to be dipped in vinegar while red hot to render it worthless as a commodity, thus to restrain the cupidity of the citizen soldiers, was in all probability not adopted from any ascetic motive. The current explanation was, without doubt, an aetiological myth, a grandiose explanation long after the commonplace event. The iron money was the survival of a time when iron was a favorite article of exchange, as it was in the Homeric age, and as it still is, as we have seen, in Africa to-day. But the Spartans were a very conservative people, and clung to their primitive money long after the superiority of other metals for coinage had been demonstrated by experience; and long after the real origin of their money had been forgotten. To explain their own backwardness, they gave, as so many other peoples have given, a religious and moral sanction to their own lack of progressiveness.†

After the introduction of metallic money there was room for a long process of development. Man had still to determine which of the metals was the most suitable for his purposes; and the actual selection which civilized man has made is the result of the survival of the fittest. There are certain qualities which we have come to look for in money, qualities which all metals seem to possess in a greater degree than any one substance, but qualities which all metals do not possess in the same

*Del Mar: *op. cit.*, p. 147.

†Enc. Brit., *Art. Money*.

degree. These are Utility, Portability, Indestructibility, Homogeneity, Divisibility, Stability of Value, Cognizability. These qualities are possessed in an especial degree by gold and silver, and in a less degree by copper. Iron was used, and is still used in many regions; but it is not the best money material because of its cheapness. It does not contain great value in small bulk, and it is not indestructible. Lead was used in classical times, and is still current in Burmah, but it is too soft to be made into good coins which will retain their stamp and be always cognizable. Tin was early adopted as a money material. It was coined by Dionysius, of Syracuse, who was the first to use it of whom we can speak with certainty; and it has remained in use as a money material ever since. In 1680, Charles II. issued tin farthings, and his example was followed by William and Mary in 1690; and it was employed in Java, Mexico, and elsewhere. But it has the defect of being too soft. Copper, either pure or in alloy, has been extensively employed, and it possesses almost all the qualities requisite, except that it does not contain great value in small bulk, and has comparatively little stability of value. Platinum is in many respects suited for currency purposes, but it is in but slight demand, and the stock on hand is very small. Consequently any change in the demand is apt to cause great fluctuations in value. Russia, which owns platinum mines in the Ural Mountains, began to coin it in 1828, but abandoned the experiment in 1845, because of the cost of striking coins. Nickel has been largely used in alloy, but it is subject to the disadvantage of fluctuations in value owing to the limited number of mines. Silver and gold are pre-eminently the metals suitable for coinage. They possess all the qualities necessary in a currency material. These qualities, of course, they do not possess in a perfect degree; but they possess them in a higher degree than any other substances. They have great utility. They contain great value in small bulk and are readily portable. Except by the slow process of wear and tear they are practically indestructible. They are almost perfectly homogeneous after they have been reduced to uniform degrees of

fineness, which can be easily done, so that equal weights of them have practically equal values. They can be easily divided into the weights and fractions desired so as to express large values and small values. They have a very large degree of stability of value, not so much perhaps as wheat, but more than most articles which could be employed as money. And lastly, they are readily recognizable and cannot be easily counterfeited, and above all, are soft enough and yet hard enough to be coinable, "so that a portion, being once issued according to proper regulations with the impress of the state, may be known to all as good and legal currency equal in weight, size and value to all similarly marked currency."*

The precious metals are simply those commodities which experience has shown to be the most suitable for general money purposes. This, or that money article, may have this or that money quality in a higher degree than gold or silver, but taking them all in all, the precious metals have been found to be the most suitable. They have survived, not because of any prejudice in favor of the metals, but because they have shown themselves to be the fittest to survive.

*Jevons : Money and the Mechanism of Exchange, p. 40.

VI.—ON THE PRESENCE OF ACID SULPHATE OF COPPER IN MIXTURES OF AQUEOUS SOLUTIONS OF SULPHURIC ACID AND COPPER SULPHATE—BY CHARLES F. LINDSAY, *Dalhousie College, Halifax, N. S.*

(Communicated on 8th May, 1899, by Prof. E. Mackay, Ph. D.)

Anton Schrader* in a paper on the "Electrolysis of Mixtures," measured the conductivity and other properties of solutions containing mixtures of sulphuric acid and copper sulphate, analysing his mixtures for the amount of acid present by titration. In his paper, no methods of any kind are given for the analyses. Prof. MacGregor† has held that Schrader's results point towards the presence of acid sulphate of copper in the solution. At the suggestion of Prof. Mackay this work was undertaken to find if any light could be obtained on this question by chemical analytical methods.

The work was carried out in the Chemical and Physical laboratories of Dalhousie College, and consisted primarily in making up solutions of sulphuric acid and copper sulphate, analysing them, and determining their densities. In the beginning the densities were taken only as a means of calculating the concentration of the mixtures from the concentration of the simple solutions. The work also included the purification of the materials used, and the calibration of burettes and pipettes.

Calibration of Burettes and Pipettes.

All burettes and pipettes were carefully calibrated, by weighing the amount of water of known temperature which they delivered. The burettes used could be read to .01 c.c. They were calibrated for every 2 c.c. throughout their length.

The pipettes, in emptying, were held against the side of the vessel into which they were being emptied, the last drops of water being removed by blowing sharply once.

* Inaugural Dissertation, Berlin, 1897.

† Trans. Roy. Soc. Canada, (2), 4, Sec. 3, 117, 1898-9.

Purification and Analysis of Copper Sulphate.

The copper sulphate was obtained as chemically pure, and after careful re-crystallization, was found to be free from iron and the members of the ammonium sulphide group.

The copper sulphate solutions were analysed by precipitating the sulphate, in known volume, with barium chloride, and weighing as barium sulphate.

The following are the results of three analyses of the same solution :—

Cu SO ₄	in 5 c.c. of solution	=	.5782	grammes.
"	"	"	= .5788	"
"	"	"	= .5790	"
Mean.....				= .5787

These figures would seem to show that my results might be in error about 0.1 per cent.

Purity and Analysis of Sulphuric Acid.

The sulphuric acid was the best obtainable from Merck, and was taken as chemically pure. The sulphuric acid solutions were analysed volumetrically with standard caustic potash, using as an indicator phenol phthalein.

The following results show with what accuracy such analyses could be carried out :—

2 c.c. H ₂ SO ₄	solution contained	.1627	grammes H ₂ SO ₄
"	"	"	"
"	"	"	"
"	"	"	"
Mean.....		=	.16253

Thus, the possible error of a single measurement would seem to be about 0.11 per cent.

Preparation and Analysis of Mixtures.

Equal volumes of the simple solutions, whose concentrations and densities were known, were mixed at 18°C. The density of the mixture being obtained, the concentration of the mixture with respect to each of the constituents, was obtainable.

The ordinary methods of acid titration are, of course, unavailable in this case, for not only does the copper sulphate itself affect alkalimetric indicators, but the sulphate is precipitated as hydroxide, by the base used for titration. The latter fact is the one used in the method of titration which was employed.

Standard caustic potash solution is added from a burette to the mixture, with constant stirring, until the solution just begins to become cloudy, owing to the beginning of the precipitation of the hydroxide of copper. I found that, using this precipitating point as an indicator, very good determinations of the acid present could be obtained; and would suggest that copper sulphate might be used as an indicator in the determination of free sulphuric acid, in cases where the ordinary indicators are of no use.

The following results of an analysis will show with what accuracy the determination of this precipitating point could be ascertained :

5 c.c. of a mixture $\text{CuSO}_4 + \text{H}_2\text{SO}_4$, began to be cloudy on				
addition of 43.88 c.c. decinormal caustic potash.				
43.97	"	"	"	"
43.99	"	"	"	"
44.86	"	"	"	"
<hr/>				
43.92 = mean.				

Thus, in these determinations, the difference between the greatest and least values would be about .3%.

A second set of determinations is added :

5 c.c. of a mixture $\text{CuSO}_4 + \text{H}_2\text{SO}_4$, began to become cloudy				
on addition of 28.94 c.c. of decinormal caustic potash.				
28.91	"	"	"	"
28.99	"	"	"	"
<hr/>				
28.95 = mean				

In this case, the difference between the greatest and least values is about .27%.

It is thus seen not only that the precipitating point is a perfectly definite one, but that it can be determined with considerable accuracy.

The next question is, whether it expresses accurately the amount of acid present.

Concentration.		H ₂ SO ₄		Error.
H ₂ SO ₄	CuSO ₄	Calculated.	Found.	
.416	.364	.2036	.2039	+.15%
.277	.727	.1356	.1357	+.08%

Column I. contains the concentration of H₂SO₄ in mixture in gramme-molecules per litre.

" II. contains the concentration of CuSO₄ in mixture in gramme-molecules per litre.

" III. contains the amt. of H₂SO₄ in grammes, calculated to be in every 5 c.c. of mixture.

" IV. contains the same, as found in every 5 c.c. of mixture.

" V. contains the percentage error.

We thus see that by this means, the sulphuric acid present can be determined with considerable accuracy.

In the above analyses, the mixture under analysis was diluted very much, the reason being, that so far the work has been only to find a good method of analysis, and not to prove or disprove the presence of acid sulphate.

But now a number of analyses were performed on the above mixtures, keeping the mixtures concentrated, and in no case was there any appreciable difference in the amount of caustic potash needed before precipitation would commence.

The results obtained from analyses of the concentrated mixtures, gave, as a rule, slightly less quantities of sulphuric acid. But this I would attribute to the fact that the precipitate would be more easily noticed in the smaller volume than in the larger.

I also made a number of determinations, using standard ammonia in place of the standard potash, but although the precipitating point could be fairly well determined, the results did not agree as well with the amount of sulphuric acid known to be present.

We thus see that this method of chemical analysis for sulphuric acid, while it gives us a good method of analysis for such mixtures, sheds no light on the presence of acid sulphate in solution.

While any recognizable decrease in the amount of sulphuric acid given up to analysis from that known to be present, would yield an almost conclusive proof of the presence of acid sulphate, the result obtained here, does not of necessity lead to the reverse conclusion.

Specific Gravity Measurements.

All specific gravity measurements were made at 18°, and are referred to water at 18°. In these measurements, a pycnometer of the form recommended by Ostwald, and holding about 25 c.c. was used.

The pycnometer was brought to 18° by being placed in a water bath, provided with a mechanical stirrer, whose temperature could easily be kept constant to 1/20 of a degree. When the liquid had come to the temperature of the bath, the meniscus was brought to the mark, the pycnometer taken out, dipped in distilled water, dried carefully with a linen towel, and weighed.

From several successive measurements of the same solution, it would appear that my measurements of density might be in error by about 5 in the fifth place of decimals.

Favre and Valson* have found that, in the case of concentrated solutions of K_2SO_4 and $CuSO_4$, and K_2SO_4 and H_2SO_4 , the density of a mixture of equal volumes of the constituents, is less than the mean value of their densities. From these results they

*Compt. Rend., 77, 907.

drew the conclusion that acid or double sulphate was present in solution. Also McKay† has noticed the same for mixtures of potassium and magnesium sulphates.

In the case of more concentrated solutions of CuSO_4 and H_2SO_4 , I have found the same result to hold. But from lack of time I was unable to push this far.

I give two of my measurements, showing the concentration and density of the constituents, the density of the mixture, and its departure from the mean value.

Parts of H_2SO_4 in 100 parts Solution.	Parts of CuSO_4 in 100 parts Solution.	Density H_2SO_4	Density CuSO_4 .	Mean Value.	Density of Mixture.	Differ- ence.
17.41	16.083	1.12586	1.19108	1.15842	1.15603	.00239
16.23	13.877	1.11525	1.14802	1.13163	1.12952	.00211

†Trans. N. S. Inst. Sci., 9, 348, 1897-98.

VII.—ON A DIAGRAM OF FREEZING-POINT DEPRESSIONS FOR
ELECTROLYTES.—BY PROF. J. G. MACGREGOR, *Dalhousie
College, Halifax, N. S.*

(Received June 20th, 1900.)

The object of this paper is to describe a diagrammatic method of taking a bird's-eye view of such knowledge as we possess of the relation of the depression of the freezing-point to the state of ionization in aqueous solutions of electrolytes, and to show that such diagrammatic study gives promise of throwing much light upon the following questions: (1.)*—Has the depression constant a common value for all electrolytes, and if so, what is it? And (2), What is the state of association, and what the mode of ionization of electrolytes, in solution?

Construction and Properties of the Diagram.

If an extremely dilute solution contain an electrolyte whose molecule, as it exists in solution, contains p equivalents, and dissociates into q free ions, and if α is its ionization coefficient and k its depression constant, the equivalent depression will be:

$$\delta = \frac{k}{p} \left(1 + \alpha (q - 1) \right).$$

If therefore we plot a diagram of curves with ionization coefficients as ordinates, and equivalent depressions as abscissae, the resulting curves must, at extreme dilution ($\alpha = 1$), be tangential to the straight lines represented by the above equation, provided the proper values of k , p , and q be employed. These straight lines, which, for shortness, we may call the tangent lines of the curves, can readily be drawn in the diagram, with any assumed value of k , and on any admissible assumptions as to the values of p and q . In the diagram on page 235 the dashed lines are the

* On this question, see also a paper recently communicated to the Royal Society of Canada, and to be published in its Transactions for 1900.

tangent lines for the electrolytes examined, on various assumptions as to constitution in solution and mode of ionization, and for $k=1.85$. They are indicated by the inscriptions 1—2, 2—3, etc., the first figure in each giving the number of equivalents in the molecule as it is assumed to exist in solution, and the second, the number of free ions into which the molecule is assumed to dissociate. Thus 1—2 is the tangent line for an electrolyte such as NaCl, on the assumption that it exists in solution in single molecules, each of which has therefore 1 equivalent, and dissociates into 2 ions. If assumed to associate in double molecules, with unchanged mode of ionization, its tangent line would be indicated by 2—4, and if the double molecules were assumed to dissociate into Na and NaCl_2 , by 2—2. The line for H_2SO_4 , on the assumption that its molecules undergo no association, and have thus 2 equivalents, and that they dissociate each into 3 ions, would be 2—3; and 4—6 would be its line if it associated into double molecules, dissociating each into 6 ions.

In a few cases dotted lines have been introduced, to show what the tangent lines would be with other values of k ,—1.83, 1.84, 1.86, 1.87, the constant used in such cases being indicated.

The curve for any given electrolyte, must start at the intersection of its tangent line with the line: $a=1$, to which point we may refer, for shortness, as the intersection of its tangent line. What its form will be, may be anticipated from the following theoretical considerations:—The equivalent depression in dilute solutions of non-electrolytes, is proportional to the osmotic pressure, P , and the dilution, V , which corresponds to the product of the pressure, p , and the specific volume, v , in the case of a gas. If pv is plotted against v , the resulting curve is convex towards the axis of v , and passes, in general, through a point of minimum value of pv . Hence, if PV , and therefore equivalent depression, be plotted against V , we may expect to get curves of the same general form. And experiment shows, in some cases at least, that we do. As in the case of gases the variation of pv is ascribed to the mutual action of the molecules and their finite volume, so in the case of solutions, the variation of PV is attributed to similar disturbing influences.

Owing to ionization, the curve of an electrolyte will differ from that of a non-electrolyte, (1) because of the change thereby produced in the number of molecules (including free ions) in unit of volume, and (2) because of the change produced in the disturbing influences referred to. The former change is doubtless the more important, and I shall assume the latter to be negligible for the present purpose. Now dissociation increases continuously with dilution. If, therefore, association of molecules does not occur, and if the mode of ionization does not change, the equivalent depression must be increased by the dissociation, in a ratio which increases continuously with dilution. The change produced in the curve by dissociation, therefore, will be a shear parallel to the equivalent depression axis, and increasing with dilution. The resulting curve will consequently remain convex towards the axis of dilution, but it will be less likely than the curve of a non-electrolyte, to exhibit the minimum point.

If, now, we plot equivalent depression against ionization coefficient, instead of dilution, the result will be the same as if we shortened the dilution ordinates of the various points of the curve just mentioned, in ratios increasing with the dilution, which process must leave the curve convex towards what was the dilution axis, but is now the ionization coefficient axis.

If, therefore, no change occur in the association of molecules or in the mode of ionization, the curve of an electrolyte on the diagram must start at the intersection of its tangent line, tangentially to that line, and bend away from it, as dilution diminishes, to the right, possibly passing through a point of minimum equivalent depression. We may speak of such a curve as the normal curve for the tangent line, corresponding to the given conditions as to constitution in solution, and mode of ionization.

If, the constitution of the electrolyte in the solution remaining constant, the mode of ionization changes as dilution diminishes, say, in such a way that the molecules dissociate, on the average, into a smaller number of ions, the equivalent depression will diminish more rapidly than it otherwise would. The curvature of the curve will therefore diminish, and may possibly become

zero, and change sign, the curve thus becoming concave towards the ionization coefficient axis, and possibly crossing the tangent line. In such a case, it will at the start coincide with the normal curve of the tangent line determined by the initial conditions as to association and mode of ionization, and at the finish, with the normal curve of the tangent line, determined by the final conditions; and between the start and the finish it will gradually change from the one to the other.

If, as dilution diminishes, association of molecules into double or other multiple molecules occurs, the mode of ionization remaining the same, the equivalent depression will be thereby made to diminish more rapidly than it otherwise would, and the general effect on the form of the curve, will be of the same kind as under the conditions just considered. But the normal curves of the tangent lines determined by the final conditions, will be quite different in the two cases.

It follows that by plotting, so far as experiment allows, the curves of observed equivalent depression against ionization coefficient, and drawing in the tangent lines for different values of the depression constant, and on different assumptions as to association and mode of ionization, we may be able to determine, with a smaller or greater probability, what the state of association and the mode of ionization are, what are the tangent lines to whose intersections the curves would run out if observations at extreme dilution could be made, and what the values of the depression constant are, to which these lines correspond.

Data for the Diagram.

To draw the experimental curves, we must have corresponding values of the depression, and of the ionization coefficient, at the freezing point, or, what in most cases would be sufficiently near, at 0°C . The former are obtained by direct measurement; but the latter only indirectly, from conductivity observations. It is not, of course, known how closely the ionization coefficients, even during the passage of the current, can thus be determined, or if the state of ionization during the passage of the

current is to be regarded as being the same as when the current is not flowing. But as it has been shown that electrically determined coefficients enable us to predict within the limit of error of observation, not only the conductivity and the results of electrolysis* of moderately dilute complex solutions, but also their density, viscosity, and other non-electrical properties,† it would appear to be probable that for moderately dilute and very dilute solutions, electrically determined coefficients are approximately exact, not only for a solution through which a current is passing, but generally.

The available data as to ionization coefficients at 0° , are unfortunately few. Whetham† has recently published some most valuable determinations, having measured the conductivity at 0° , of series of solutions down to extreme dilution, with what one may call *appareil de luxe*, and found the ratio of the equivalent conductivity to the maximum equivalent conductivity. For neutral salts, his coefficients must inspire great confidence. But in the case of the acids, they seem to me to be probably too high. For the maximum equivalent conductivity of an acid is probably lower than it would be, were it not for the disturbing influence whatever it is, which makes the equivalent-conductivity-concentration curve not only reach, but pass through a maximum point.

Archibald and Barnes,‡ working in my laboratory, measured the conductivity at 0° and 18° for series of solutions, down to dilutions, at which the ratio of the two conductivities became constant; and assuming that the same ratio would hold at extreme dilution, they calculated the equivalent conductivity at extreme dilution for 0° from Kohlrausch's values for 18° . They used this method only because appliances were not available, with which observations at extreme dilution could be made. If

* MacGregor: Trans. Roy. Soc. Can. (2), 4, Sec. 3, 117, 1898.

† MacGregor: Trans. N. S. Inst. Sci. 9, 219, 1896-7, and Phil. Mag. (5), 43, 46 and 99, 1897. Also Archibald: Trans. N. S. Inst. Sci. 9, 335, 1897-8, and Barnes: *Ibid.*, 10, 49, and 113, 1899-1900.

‡ Ztschr. f. phys. Chem., 33, 344, 1900.

† Archibald: Trans. N. S. Inst. Sci., 10, 33, 1898-9. Barnes: *Ibid.*, 10, 139, 1899-1900, and Trans. Roy. Soc. Canada, (2), 6, —, 1900.

the ratio mentioned really does become constant as dilution increases, the method is likely to give coefficients with too low or too high values, according as the ratio at moderate dilutions diminishes or increases with dilution (it was found to increase with KCl and K_2SO_4 .) For it will probably become constant within the limit of error of observation, before it has really reached constancy. And if it changes with dilution in a slightly wavy manner, even though on the whole tending to constancy, it may be regarded as having become constant, when really passing through a maximum or a minimum point.

Dégusne's* observations on the variation of conductivity with temperature between 2°C and 34° have enabled me, by the method just mentioned, to make rough determinations of the ionization coefficients at 0° in some cases, on the assumption that his empirical constants might be used down to 0° . According to Dégusne's observations, the ratio of the conductivities at 0° and 18° usually changes gradually down to dilutions of 1,000 litres per gramme-equivalent, and between that and 2,000, undergoes rapid change. As observations at great dilution are attended by considerable difficulty, I have assumed that these sudden changes were probably due to errors of observation. If they were not, my Dégusne coefficients (for which Dégusne himself is of course not to be held responsible) may be considerably out.

In some cases, I have obtained coefficients from the above data by extrapolation, in order to make use of available depression data. In such cases I have plotted, side by side, ionization-coefficient-concentration curves, for both 0° and 18° , using values for 18° based on Kohlrausch's conductivities, and I have then produced the 0° curve beyond the limit of observation, under the guidance of the 18° curve.

I have used all the accessible observations of depression in the case of the electrolytes for which data were available for determining the ionization coefficients at 0° , including observations by

* *Temperatur-Coëfficienten des Leitvermögens sehr verdünnter Lösungen*. Dissertation, Strassburg, 1895. See also Kohlrausch u. Holborn: *Leitvermögen der Elektrolyte*, Leipzig, 1898.

Arrhenius,¹ Raoult,² Loomis,³ Jones,⁴ Abegg,⁵ Wildermann,⁶ Ponsot,⁷ Archibald⁸ and Barnes⁸. The methods used by these observers are, for the most part, well known. Archibald and Barnes used modified forms of Loomis's method. Arrhenius's observations, and some of Raoult's, were made before important improvements in freezing-point determinations had been recognised as necessary.

In cases in which there was but one series of observations available, I have plotted the actual observations in the diagram, though sometimes smoothing the curves a little. In cases in which two or more series were available, I first plotted the various observations, and then drew mean curves, making them represent all the observations as well as I could, but giving greater weight to recent observations than to those of earlier date, and to long series of consistent observations than to short series, or to series which were more erratic.

The following table gives the data employed in plotting both the curves given in the diagram, and those not so given, which are referred to below. The table includes the concentration in gramme-equivalents per litre, the ionization coefficient at 0°, and the equivalent depression in degrees centigrade per gramme-equivalent in one litre of solution. The interpolated coefficients are indicated by *i*, and those extrapolated by *e*, and the observers from, or by the aid of, whose observations they were obtained, by A, B, D, W, representing Archibald, Barnes, Déguisne and Whetham. Non-significant figures are printed in italics.

¹ Ztschr. f. phys. Chemie. 2, 491, 1888.

² *Ibid.*, 2, 501, 1888, and 27, 617, 1898.

³ Phys. Review, 1, 199 and 274, 1893-4; 3, 270, 1896, and 4, 273, 1897.

⁴ Ztschr. f. phys. Chem., 11, 110 and 529, 1893; and 12, 623, 1893.

⁵ *Ibid.* 20, 207, 1896.

⁶ *Ibid.* 19, 233, 1896.

⁷ Recherches sur la Congélation des Solutions Aqueuses: Paris, Gauthier-Villars, 1896.

⁸ *Loc. cit.*

Gramme-equivalent per litre.	Ionization Coefficient at 0°C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization Coefficient at 0°C.	Equivalent Depression.
KCl. (Barnes.)			KCl. (Abegg.)		
.0001	.989	.....	.00488	.976 i. W.	3.70
.0002	.986	.....	.00972	.962 "	3.63
.0005	.977	.....	.0118	.958 "	3.64
.001	.971	.....	.0145	.953 "	3.63
.005	.944	.....	.0193	.944 "	3.53
.010	.930	.....	.0237	.917 i. B.	3.51
.03	.910	3.533	.0240	.917 "	3.49
.05	.892	3.504	.0286	.912 "	3.51
.08	.871	3.470	.0354	.904 "	3.50
.10	.862	3.458	.0469	.895 "	3.47
.20	.832	3.398	.0583	.887 "	3.45
.30	.819	3.390	.0697	.878 "	3.43
.40	.804	3.372			
KCl. (Loomis.)			KCl. (Wildermann.)		
.01	.943 i. B.	3.60	.009818	.943 i. B.	3.538
.02	.923 "	3.55	.009822	.943 "	3.583
.03	.910 "	3.52	.01954	.924 "	3.542
.035	.905 "	3.53	.03883	.900 "	3.515
.05	.892 "	3.50	.03884	.900 "	3.532
.1	.862 "	3.445	.07652	.873 "	3.491
.2	.832 "	3.404	.07668	.873 "	3.487
.4	.804 "	3.353			
KCl. (Jones.)			KCl. (Ponsot.)		
.001	.992 i. W.	3.80	.0234	.915 i. B.	3.419
.00299	.983 "	3.6789	.0439	.896 "	3.417
.00499	.976 "	3.7074	.1465	.846 "	3.413
.00698	.970 "	3.6246	.1688	.840 "	3.406
.00897	.965 "	3.6120	.2344	.827 "	3.392
.01095	.960 "	3.5982	.2456	.825 "	3.375
.02	.944 "	3.5750	.2472	.825 "	3.378
.04	.897 i. B.	3.5325	.2544	.824 "	3.377
.0592	.885 "	3.5067			
.078	.873 "	3.4923	NaCl. (Barnes.)		
.09646	.863 "	3.4688	.0001	.996	.....
.2	.832 "	3.4300	.0002	.991	.....
.28	.821 "	3.41071	.0005	.982	.....
KCl. (Raoult.)			.001	.974	.....
.01445	.953 i. W.	3.523	.005	.955	.....
.02895	.933 "	3.561	.010	.936	.....
.05825	.904 e. W.	3.478	.03	.896	3.573
.1168	.878 "	3.431	.05	.877	3.536
			.08	.860	3.530
			.10	.850	3.515
			.20	.815	3.443
			.30	.787	3.431
			.40	.765	3.412

Gramme-equivalent per litre.	Ionization Coefficient at 0°C.	Equivalent Depression.
NaCl. (Loomis.)		
.01	.936 i. B.	3.674
.02	.916 "	3.597
.03	.896 "	3.560
.04	.886 "	3.541
.05	.878 "	3.531
.06	.870 "	3.529
.07	.864 "	3.510
.08	.860 "	3.501
.09	.855 "	3.494
.10	.850 "	3.484
.20	.815 "	3.439
NaCl. (Jones.)		
.001	.974 i. B.	3.7500
.002	.967 "	3.7500
.02999	.963 "	3.683
.004	.959 "	3.650
.004998	.955 "	3.681
.005995	.950 "	3.678
.006995	.947 "	3.631
.007985	.942 "	3.628
.008985	.939 "	3.628
.01	.936 "	3.605
.02	.915 "	3.578
.0298	.896 "	3.544
.0395	.887 "	3.538
.04955	.878 "	3.519
.05975	.870 "	3.507
.0697	.865 "	3.500
.0790	.861 "	3.492
.0882	.856 "	3.483
.0973	.851 "	3.477
.1063	.848 "	3.469
.15	.831 "	3.447
.1925	.818 "	3.418
.2329	.805 "	3.414
.300	.787 "	3.410
NaCl. (Raoult.)		
.0300	.896 i. B.	3.656
.0584	.870 "	3.550
.1174	.843 "	3.473
.2370	.804 "	3.465

Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.
NaCl. (Abegg.)		
.00241	.965 i. B.	3.91
.00478	.956 "	3.91
.00714	.945 "	3.84
.00948	.937 "	3.82
.01180	.931 "	3.70
.01410	.925 "	3.66
.0221	.906 "	3.56
.0439	.882 "	3.57
.0653	.867 "	3.55
.0871	.856 "	3.50
.1083	.847 "	3.47
NaCl. (Arrhenius.)		
.0467	.879 i. B.	3.79
.117	.843 "	3.64
.194	.816 "	3.54
.324	.781 "	3.51
NaCl. (Ponsot.)		
.1318	.836 i. B.	3.445
.1808	.821 "	3.418
.2016	.814 "	3.413
.2248	.808 "	3.403
.2288	.806 "	3.405
.3136	.784 "	3.402
HCl. (Barnes.)		
.001	.996	.....
.002	.995	.....
.005	.989	.....
.010	.984	.....
.0207	.971	3.638
.0518	.955	3.595
.0829	.941	3.569
.104	.932	3.556
.207	.909	3.585
.305	.897	3.633
.40	.884	3.638

Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.
HCl. (Loomis.)			HNO ₃ . (Loomis.)		
.01	.982 i. B.	3.61	.01	.977 i. D.	3.50
.02	.972 "	3.60	.02	.967 e. D.	3.56
.05	.955 "	3.59	.03	.959 "	3.53
.1	.933 "	3.546	.05	.950 "	3.51
.2	.910 "	2.565			
.3	.897 "	3.612			
HCl. (Jones.)			HNO ₃ . (Jones.)		
.001222	.996 i. B.	3.7643	.001054	.994 i. D.	3.7951
.003662	.991 "	3.7411	.003158	.989 "	3.7682
.006112	.987 "	3.7467	.005253	.982 "	3.7693
.008538	.984 "	3.7033	.007378	.981 "	2.7409
.01222	.979 "	3.6743	.009456	.978 "	3.7331
.03619	.962 "	3.6750	.01153	.975 e. D.	3.7294
.05919	.951 "	3.6611	.03119	.958 "	3.7179
.08127	.940 "	3.5856	.05103	.949 "	3.7076
.1025	.933 "	3.5609			
.1228	.928 "	3.5692			
NH ₄ Cl. (Loomis.)			KOH. (Loomis.)		
.01	.951 i. D.	3.56	.01	.965 i. D.	3.43
.02	.931 "	3.56	.02	.956 e. D.	3.45
.035	.914 "	3.50	.05	.943 "	3.44
.05	.900 "	3.48	.1	.932 "	3.43
NH ₄ Cl. (Jones.)			KOH. (Jones.)		
.001	.987 i. D.	3.8	.001069	.983 i. D.	3.7418
.00599	.963 "	3.7062	.003202	.973 "	3.7477
.00997	.951 "	3.6108	.005327	.969 "	3.7169
.0595	.892 e. D.	3.5143	.007443	.967 "	3.6947
			.009550	.965 "	3.6859
			.01069	.964 e. D.	3.6296
			.03163	.950 "	3.6263
			.05174	.942 "	3.5756
			.07481	.935 "	3.6142
KNO ₃ . (Loomis.)			BaCl ₂ . (Loomis.)		
.01	.938 i. D.	3.46	.02	.860 i. W.	2.495
.02	.915 "	3.52	.04	.820 e. W.	2.475
.025	.899 "	3.46	.1	.768 "	2.385
.05	.876 "	3.41	.2	.724 "	2.345
.1	.832 e. D.	3.314	.4	.658 "	2.3275
.2	.789 "	3.194			

Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.
Ba Cl ₂ . (Jones.) *			K ₂ SO ₄ . (Archibald.)—Continued.		
.002	.953 i. W.	2.7500	.002	.925	.....
.003996	.932 "	2.7027	.004	.904	.....
.005988	.917 "	2.6720	.005	.895	.....
.008	.906 "	2.6250	.008	.871	.....
.009984	.896 "	2.6142	.010	.859	.....
.011964	.889 "	2.5828	.050	.755	2.370
.01394	.880 "	2.5753	.053	.748	2.356
.01592	.872 "	2.5754	.060	.743	2.345
.01738	.866 "	2.5560	.070	.732	2.327
.02	.860 "	2.5500	.080	.722	2.314
Ba Cl ₂ . (Ponsot.)			.100	.705	2.285
.00926	.900 i. W.	2.484	.200	.645	2.161
.00994	.897 "	2.515	.250	.629	2.118
.01030	.895 "	2.524	.300	.616	2.080
.01290	.887 "	2.481	.350	.606	2.056
.01304	.883 "	2.531	.400	.598	2.032
.02500	.845 "	2.480	.450	.591	2.014
.02740	.839 "	2.482	.500	.588	1.990
.03310	.827 e. W.	2.477	.600	.583	1.950
.03588	.822 "	2.481	.700	.580	1.916
.03676	.820 "	4.475	K ₂ SO ₄ . (Loomis.)		
.03824	.818 "	2.453	.02	.821 i. A.	2.46
.04810	.803 "	2.453	.04	.772 "	2.38
.05112	.802 "	2.445	.1	.705 "	2.271
.05520	.796 "	2.446	.2	.645 "	2.1585
.0620	.790 "	2.436	.4	.598 "	2.0335
.0680	.785 "	2.426	.6	.583 "	1.9455
.0774	.771 "	2.416	K ₂ SO ₄ . (Jones.)		
.2060	.717 "	2.316	.002	.925 i. A.	2.725
.2095	.716 "	2.320	.003992	.904 "	2.693
.2235	.710 "	2.309	.005990	.886 "	2.663
.3100	.685 "	2.297	.007970	.871 "	2.641
.3280	.682 "	2.308	.009930	.859 "	2.613
.3470	.679 "	2.317	.012	.850 "	2.613
K ₂ SO ₄ . (Archibald.)			.01396	.842 "	2.593
.0001	.953	.....	.01590	.836 "	2.582
.0002	.976	.....	.01784	.829 "	2.545
.0004	.969	.....	.01976	.823 "	2.525
.0005	.964	.....	.03949	.771 "	2.469
.0006	.960	.....	.0579	.745 "	2.413
.0008	.953	.....	.07556	.727 "	2.372
.001	.946	.....	.10	.705 "	2.307

* I have by oversight used one of Jones' two sets of observations, instead of the mean of his two sets; but the curve of mean values would not differ appreciably from the curve of single values.

Gramme-equivalent per litre.	Ionization coefficient at 0° C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization coefficient at 0° C.	Equivalent Depression.
$K_2 SO_4$. (Jones).— <i>Continued.</i>			$Na_2 SO_4$. Archibald.—(<i>Continued.</i>)		
.116	.692 i. A.	2.289	.250	.600	2.120
.1357	.677 "	2.231	.300	.578	2.084
.152	.668 "	2.208	.350	.561	2.045
.16765	.661 "	2.197	.400	.546	2.025
.1826	.624 "	2.178	.450	.535	1.993
.19685	.647 "	2.160	.500	.525	1.975
			.600	.511	1.925
			.700	.501	1.890
$K_2 SO_4$. (Abegg)			$Na_2 SO_4$. (Loomis.)		
.00876	.865 i. A.	2.79	.02	.821 i. A.	2.545
.01306	.846 "	2.60	.04	.771 "	2.435
.01734	.829 "	2.47	.10	.694 "	2.295
.0216	.815 "	2.43	.20	.624 "	2.170
.0258	.803 "	2.40	.40	.546 "	2.036
.0299	.794 "	2.385	.60	.511 "	1.938
$K_2 SO_4$. (Arrhenius.)			$Na_2 SO_4$. (Raoult.)		
.0728	.729 i. A.	2.53	.1174	.678 i. A.	2.39
.182	.654 "	2.225	.2866	.584 "	2.18
.454	.590 "	2.09	.426	.540 "	2.68
$K_2 SO_4$. (Ponsot.)			$Na_2 SO_4$. (Arrhenius.)		
.0724	.731 i. A.	2.307	.056	.741 i. A.	2.515
.0752	.726 "	2.301	.1402	.661 "	2.325
.2295	.635 "	2.113	.234	.607 "	2.205
.2360	.633 "	2.110	.390	.549 "	2.095
.4140	.596 "	2.012			
.4280	.594 "	2.002			
$Na_2 SO_4$. (Archibald.)			$H_2 SO_4$. (Barnes.)		
.005	.893	.....	.002	.883	.....
.008	.870	.....	.004	.831	.....
.010	.859	.....	.010	.783	.....
.050	.752	2.382	.020	.734	.....
.055	.743	2.371	.0406	.720	2.224
.060	.736	2.360	.1016	.644	2.084
.070	.722	2.340	.1622	.609	2.017
.080	.712	2.320	.204	.596	1.979
.100	.694	2.286	.406	.569	1.940
.200	.624	2.165	.608	.553	1.918

Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.
H_2SO_4 . (Loomis.)			H_2SO_4 . (Wildermann.)— <i>Continued.</i>		
.02	.770 i. B.	2.247	.06244	.688 i. B.	2.098
.04	.721 "	2.155	.09216	.653 "	2.049
.10	.645 "	2.065	.1358	.622 "	2.004
.20	.598 "	1.984	.1930	.599 "	1.970
.40	.570 "	1.925			
H_2SO_4 . (Jones.)			Na_2CO_3 . (Loomis.)		
.002696	.962 i. W.	2.7077	.02	.735 i. D.	2.535
.007182	.906 "	2.5620	.04	.684 "	2.465
.011650	.870 "	2.5150	.10	.611 e. D.	2.32
.016106	.844 "	2.4091			
.02054	.823 "	2.3710	Na_2CO_3 . (Jones.)		
.02696	.796 "	2.3108	.003030	.859 i. D.	2.805
.07100	.678 i. B.	2.2183	.008068	.803 "	2.764
.11358	.633 "	2.0514	.013090	.770 "	2.758
.15472	.612 "	1.9952	.018096	.743 "	2.741
.19450	.598 "	1.9732	.02120	.730 "	2.722
.2330	.586 "	1.9498	.04802	.670 "	2.676
H_2SO_4 . (Ponsot.)			.07736	.632 e. D.	2.494
.0149	.790 e. B.	2.282	.09588	.613 "	2.335
.0181	.770 "	2.265			
.0365	.726 "	2.192	$MgSO_4$ (Loomis.)		
.0395	.720 i. B.	2.203	.02	.594 i. D.	1.331
.0503	.706 "	2.147	.04	.522 "	1.277
.0669	.681 "	2.108	.06	.485 "	1.237
.0727	.674 "	2.091			
.0876	.658 "	2.043	$MgSO_4$ (Jones.)		
.2570	.587 "	1.895	.002	.817 i. D.	1.7000
.2580	.587 "	1.899	.003996	.773 "	1.6767
.4476	.565 "	1.850	.005998	.728 "	1.6533
.4516	.565 "	1.849	.007976	.694 "	1.6174
.8872	.535 "	1.859	.009960	.669 "	1.6064
H_2SO_4 . (Wildermann.)			.011994	.651 "	1.5913
.009208	.889 i. W.	2.422	.01400	.634 "	1.5785
.009216	.889 "	2.388	.015972	.614 "	1.5590
.016808	.842 "	2.297	.017940	.608 "	1.5496
.016834	.842 "	2.293	.019904	.596 "	1.5323
.01690	.840 "	2.325	.03950	.521 "	1.4912
.03206	.776 "	2.190	.05872	.502 "	1.4391
.03212	.735 i. B.	2.183			
.06238	.688 "	2.10			

Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.	Gramme-equivalent per litre.	Ionization Coefficient at 0° C.	Equivalent Depression.
$H_3 PO_4$ (Loomis.)			$H_3 PO_4$ (Jones).		
.03	.614 i. D.	0.94	.003279	.881 i. D.	1.1894
.06	.513 "	0.893	.009843	.771 "	1.1515
			.019605	.669 "	1.0967
			.027705	.627 "	1.0721
			.03279	.602 "	1.0522

The curves of the diagram are so labelled with the initial letters of observers' names, (Ab for Abegg), as to show both the depression observations, on which they are based, and the ionization coefficients used in plotting them. Thus the inscription KCl (J—W), means that Jones' depressions and Whetham's coefficients were used; H_2SO_4 (J L B—B), that the curve is a mean curve based, mainly at least, on depression observations by Jones, Loomis, and Barnes, and plotted with Barnes' coefficients. The limits of concentration for the curves, are indicated also, in gramme-equivalents per litre.

Some of the curves are entered on an inset, drawn on four times the scale of the main diagram.

In interpreting the curves, we must not only bear in mind what has been said above about the probable accuracy of the ionization coefficients, but must in addition note the tendency exhibited by the curves of the various observers, as dilution increases, to run off at great dilution in directions characteristic of the observers, to the left or right relatively to the course pursued by them at moderate dilution. Thus Abegg's curves (see NaCl, KCl, K_2SO_4), and Jones's (see NaCl, KCl, NH_4Cl , HCl) run off to the right. So do Arrhenius's in a marked manner. Raoult's tendency is also to the right, (see NaCl; his K_2SO_4 , not plotted, shows it also; his most dilute KCl observation, he himself clearly regards as accidentally out.) On the other hand, Loomis's curves (see HCl, KNO_3 , NH_4Cl , $BaCl_2$) go to the left.

So do Ponsot's, and probably Wildermann's (not plotted), and I gather from Ponsot's diagrams of Pickering's observations, to which I have not access, that Pickering's also have the leftward tendency. Archibald's and Barnes' curves show less tendency to diverge than those of any other observers. And although this may be partially, it is not wholly, due to their having worked at moderate dilutions only. For in several cases, pointed out below, the curves of other observers start on a divergent course within their limit of dilution. But the fact that their curves usually agree with Loomis's, would lead one to suspect them of a leftward tendency.

The divergence, as shown on the diagram, is most marked in the case of highly dissociated electrolytes (NaCl , HCl , etc.) in which, at great dilution, the rate of increase of ionization with dilution is small, the curves being crushed up, therefore, into a small space. But it is obvious also, in the K_2SO_4 curves (especially Abegg's) and the BaCl_2 curves (including Ponsot's, not shown). And although for MgSO_4 and H_3PO_4 , whose ionization increases rapidly with dilution, the single curves do not reveal it, the relative positions of the two curves in each case are what they might be expected to be, if they were tending unduly, Jones's to the right, and Loomis's to the left.

This tendency is explicable at once, when we reflect that as it is equivalent depression that is plotted, the errors of the observations are brought into greater and greater prominence as dilution increases. According, therefore, as the characteristic error of an observer's method of measuring total depression is positive or negative, will his curves of equivalent depression diverge at great dilution to the right or left of their true course. And they must diverge even if the error is very small.

The equivalent depression curves of single observers are therefore open to grave suspicion at high dilutions; and since one can never be sure that the errors of different methods will even approximately neutralise one another, mean curves are, at high

dilution, not much more trustworthy than their components.* It is much safer, therefore, to base conclusions as to depression constant on moderate dilution curves, although the conclusions they admit of may not be so exact as we might wish.

Discussion of the Curves.

Electrolytes such as NaCl , HNO_3 , KOH , have 1 equivalent in the single molecule, and 2 ions. If, therefore, they exist in solution in single molecules, their curves should be normal 1—2 curves. If the molecules are all double or triple, the curves should be 2—4 or 3—6 curves, provided the association does not involve change in the mode of ionization. If it does, they may be 2—2, or 3—4, 3—3, 3—2 curves respectively, according to the change that may occur. If the molecules are single at extreme dilution, but become double or triple as dilution diminishes, the curves should start as 1—2 curves, and undergo the appropriate transformation.

The electrolyte for which we have the most complete and trustworthy data, is KCl . The LB—B curve is based on two series of observations in close agreement and by a method exhibiting less divergence than the others. Jones's runs a little to the right of it; Abegg's a little to the left. Both Raoult's and Wildermann's cross it, the latter being somewhat steeper, the former less steep. Ponsot's

* It follows that it is inadmissible to proceed as Raoult has done in determining depression constants, (*loc. cit.* p. 658), viz., by selecting high dilution curves which are in agreement, and applying extrapolation to a mean curve derived from them; for such procedure may mean the selection of observations made by methods which have characteristic errors of the same sign. In fact, a mean curve based on observations which agree well at low dilution, but disagree markedly at high dilution, would be likely to give a better result, as more probably combining observations with small characteristic errors of opposite sign. Raoult's procedure is open to other objections. For (1) his curves of equivalent depression against total depression, make series of observations appear to be in greater disagreement than they really are, and are thus not helpful in making a judicious selection of observations to be used; and (2.) extrapolation of such curves not only gives a result affected by the average of the characteristic errors of the observations used, but also neglects the possibility, in some cases the probability, that owing to change in association and mode of ionization, the law of the change of curvature may be very different beyond the limits of observation, from what it is within these limits.

coincides with the lower part, but in the upper part diverges to the left. In form the curve is thus probably trustworthy. But being plotted with Barnes' coefficients it may be too high or too low. The R—W and J—W curves (see inset) are not open to this suspicion, but at the dilutions to which even their lower and more trustworthy parts apply, they may have begun to diverge unduly rightwards. If the L B—B curve (see inset) be raised about 2.5 per cent., as is shown to be necessary by a comparison of Whetham's and Barnes' coefficients, it comes into a position to the left of the R—W and J—W curves, the usual relative position of the curves of these observers. Loomis's own curve for somewhat greater dilutions than those of the L B—B curve, when plotted with Whetham's coefficients, coincides very nearly with the boundary line of the inset; Wildermann's is a little to the left of Loomis's, and somewhat steeper. Both exhibit a slight rightward bending, as do all the others.

It would be difficult to draw a mean curve with any confidence; but any such curve would run about midway between the 1—2 and 2—4 (1.85) lines, would have a slight rightward bending at its upper end, and if produced with diminishing curvature, would run out to a point a little to the right of the 1—2 (1.85) intersection.

If this intersection were the starting point of the curve, and if there were no association, the curve should lie wholly to the right of the 1—2 (1.85) line. If, as dilution diminished, sufficient doubling of molecules with unchanged mode of ionization should occur, the curve, after first bending away from that line to the right, would change its curvature, bend towards the line and cross it, and then run towards, and finally away from, the 2—4 line, as the mean curve appears to do.

As the 2—2 line is far to the left, the mean curve might be accounted for also, on the assumption of a very slight formation of double molecules dissociating into two ions; and a slight formation of such molecules would probably involve no greater variation of the migration numbers with concentration than has been observed.

If the 1—2 (1.86) intersection, were assumed as the starting point of the curve, the mean curve would cut the 2—4 (1.86) line. If, therefore, association in molecules with unchanged mode of ionization were assumed, some formation of triple molecules would be indicated, and if the associated molecules were assumed to dissociate into two free ions, a greater extent of such association would be indicated. Thus, with this starting point, less probable assumptions as to association must be made, to account for the observations.

If the 1—2 (1.84) or even the 1—2 (1.845) intersection were taken as the starting point, the curve must bend considerably to the left before running out,—of which bending none of the experimental curves give any indication whatever.

The most probable conclusion, then, that we can draw from the observations, is that the depression constant is 1.85, with a limit of error of .01, or perhaps .005, that the electrolyte has single molecules at great dilution, and that as dilution diminishes, either double molecules with unchanged mode of ionization form to a considerable extent, or double molecules dissociating into two ions, to a small extent.

Loomis's and Barnes' observations, on which the NaCl (L B—B) curve is based, are also in close agreement; but as Loomis's curve for slightly greater dilution bends slightly to the right, the upper part of the L B—B curve should probably have greater curvature. Jones' curve for moderately dilute solutions runs a little to the left of it, and at higher dilutions diverges markedly to the right, as separately shown. Abegg's observations are on both sides of it, but at higher dilutions his curve also goes to the right. Raoult's touches it, but goes off to the right. Arrhenius's is considerably to the right, and goes widely rightward at greater dilutions. Ponsot's is a little to the left. As the L B—B curve is plotted with Barnes' coefficients, it is probably too low. If it be raised about as much as was found necessary in the case of the KCl curve, it will lie along the 1—2 line, or a little above or below it, with its upper end, as drawn, so directed, as to run out probably at a point nearer the

1—2 (1.85) intersection, than either the 1—2 (1.83) or the 1—2 (1.87) intersection. Thus the defective data as to ionization prevent our drawing a more definite conclusion than that the association indicated, if any, is less than in the case of KCl, and that the depression constant is 1.85, with a limit of error of perhaps .02.

The HCl curve is interesting as exhibiting a point of minimum equivalent depression. The observations on which the L B—B curve is based, are in good agreement. Jones' curve almost coincides with it in the lower part, but goes off to the right in the upper part and at higher dilutions, as shown separately. Loomis's curve at higher dilutions (also separately shown) goes to the left, but in a less marked manner. As drawn, the upper part of the mean curve lies between the 1—2 and 2—4 (1.85) lines, and it is running out to a point a little beyond the 1—2 (1.86) intersection (see inset). But as it is plotted with Barnes' co-efficients it is perhaps too low. If raised 1 or 2 per cent. it would appear to run out at some point between the 1—2 (1.84) and 1—2 (1.86) intersections. The data are of course very defective; but they are consistent with a depression constant of about 1.85, and they seem to indicate a greater extent of association than in the case of KCl.

The L—D and J—D curves for NH_4Cl are not in agreement, having the usual relative position of Loomis's and Jones' curves. A mean curve based on their lower parts would be slightly to the left of the 1—2 (1.85) line, and directed to a point considerably to the right of the 1—2 (1.86) intersection. It might thus indicate anything between a high value of the depression constant accompanied by very considerable association of molecules, and a constant of about 1.85, with no association in dilute solutions, and only a slowly increasing association in stronger solutions.

The HNO_3 curve (see inset) is a mean curve based on Loomis's and Jones's. Both are beyond the bounds of the inset, the former to the left, the latter to the right. Neither this curve nor that of KNO_3 is sufficiently trustworthy to warrant any

close inspection, but both are clearly consistent with the 1.85 value of the depression constant. If the leftward bending of the KNO_3 curve in its lower part were actual, as well as the position of the curve, the formation of triple molecules might be indicated. But being a Loomis curve, it is open to the suspicion of being as a whole, too far to the left; and it is plotted with doubtful coefficients.

The KOH curves, Loomis's on the main diagram and Jones's on the inset, are useful only to illustrate the difficulty of making concordant observations by different methods. As usual, Loomis's is to the left, and Jones's to the right.

Electrolytes such as BaCl_2 , H_2SO_4 , Na_2CO_3 , have 2 equivalents in the single molecule, which may dissociate into 3 or into 2 ions. If there is no association, they will therefore have 2—3 or 2—2 curves, according to the mode of ionization. If there is complete doubling of molecules, the curves will be 4—6 or 4—4 curves, provided the doubling does not involve change in mode of ionization. Otherwise they might be 4—5, 4—3 or 4—2 curves. (The corresponding tangent lines are so far to the left of the experimental curves that they are not entered on the diagram.) If the molecules are associated in threes, the curves will be 6—9 or 6—6 curves, with the above proviso.

Both Loomis's and Jones' curves for BaCl_2 are shown on the diagram, plotted with Whetham's coefficients (rough extrapolated values, however, in the case of the former). Ponsot's curve agrees very closely with Loomis's. Bearing in mind the rightward and leftward tendencies of Jones's and Loomis's curves, respectively, we may conclude from the curves of the diagram that the actual curve runs down to the right of the 2—3 line, bending away from it to the right, and that it would intersect the $\alpha=1$ line at a point between the 2—3 (1.85) and 2—3 (1.87) intersections, probably nearer the former than the latter. The curve is thus, so far as we can judge, a normal 2—3 ($1.85 \pm .01$) curve, running, however, very close to the 2—3 line. The diagram, therefore, indicates that BaCl_2 exists in solution in single molecules, dissociating into 3 ions, at least for the most part, and that it has a depression constant nearer 1.85 than 1.87.

The H_2SO_4 (J—W) curve for high dilutions, being a Jones curve, is probably too far to the right, and being plotted with Whetham's coefficients, is probably too high. Wildermann's curve for high dilutions runs parallel to it, considerably to the left. The J L B—B curve, for lower dilutions, is very nearly coincident with Barnes' curve, and in its lower part with Jones's and Loomis's as well. But in the upper part, Jones' curve goes off markedly to the right, and Loomis's markedly to the left. Wildermann's is slightly to the left at the lower end, and diverges somewhat leftwards in the upper part. Ponsot's runs nearly parallel to it, somewhat to the left, and diverging to the left at higher dilutions. The J L B—B curve is thus trustworthy as to form; but being plotted with Barnes' coefficients, it is probably too low. The actual curve would thus appear to cross the 2—3 (1.85) line not far from its starting point, bend towards the 4—6 line, and run down below that line, finally bending slightly towards it. Its course is therefore what it would be if it started as a 2—3 curve, for $k=1.85$ or thereabout, changed its curvature at a somewhat early stage, and tended to be transformed slowly into either a double molecule curve or a 2—2 curve, or perhaps both. The diagram would therefore indicate that at extreme dilution H_2SO_4 exists in solution in single molecules, dissociating into three ions, that at an early stage and in a somewhat marked manner, either doubling of molecules sets in, or partial dissociation into two ions, or perhaps both, that the change increases slowly and steadily as dilution diminishes, and that at a concentration of about 0.6, if the coefficients at this concentration are to be trusted, the change is increasing in rate; also that the depression constant may quite readily be about 1.85.

The K_2SO_4 (L J A—A) curve, is based on series of observations which in the main are in good agreement. It very nearly coincides with the Loomis and Archibald curves, and Ponsot's runs down slightly to the left. In its lower part it coincides with the Jones curve, but in its upper part the Jones curve, which is separately represented for great dilutions, runs off to the right. Abegg's curve for higher dilutions runs even more

markedly to the right, although it is farther to the left at its lower end. Arrhenius's is considerably to the right, and diverges widely rightwards. The Na_2SO_4 (L A—A) curve is also almost coincident with both the Loomis and the Archibald curves. Both Raoult's and Arrhenius's are considerably to the right, and diverge slowly rightwards. Such of these curves as are entered on the diagram, being plotted with Archibald's coefficients, are probably somewhat too high or too low, as the case may be. Those for great dilutions are too discordant to admit of discussion. The mean curves for both salts have the same general form, and run down, as drawn, a little below the 2—3 line. Their upper ends are so directed as to suggest their running out at the 2—3 (1.85) intersection, or thereabout. At their lower ends they turn sharply to the left and cross the 2—3 line, going towards the region of the double molecule curves, or of the 2—2 curve. The turns are too sharp, and the 4—6 and 6—9 lines too near, to make their transformation into double or triple molecule curves, with unchanged ionization, probable. The diagram suggests rather their transformation into 4—5, 4, or 2 or 2—2 curves. If this be accepted, it means that at extreme dilution these sulphates exist in solution in single molecules, dissociating into three ions, that partial dissociation into two ions or doubling of molecules sets in, apparently at an early stage, but increases more slowly than in the case of H_2SO_4 , until the dilution has been considerably diminished, when it undergoes a rapid increase. A close determination of the depression constant cannot be made; but even if the curves have to be either raised or lowered a little, and if, Loomis's tendency being leftward, their upper parts have to be shifted somewhat to the right, they will be consistent with its being about 1.85.

The Na_2CO_3 curves are too discordant to form a basis for discussion. But either Loomis's curve or a mean curve, or even Jones's curve itself, is quite consistent with a depression constant of about 1.85; and both curves indicate the occurrence of rapid association or of rapid change of ionization after considerable diminution of dilution. The fact that

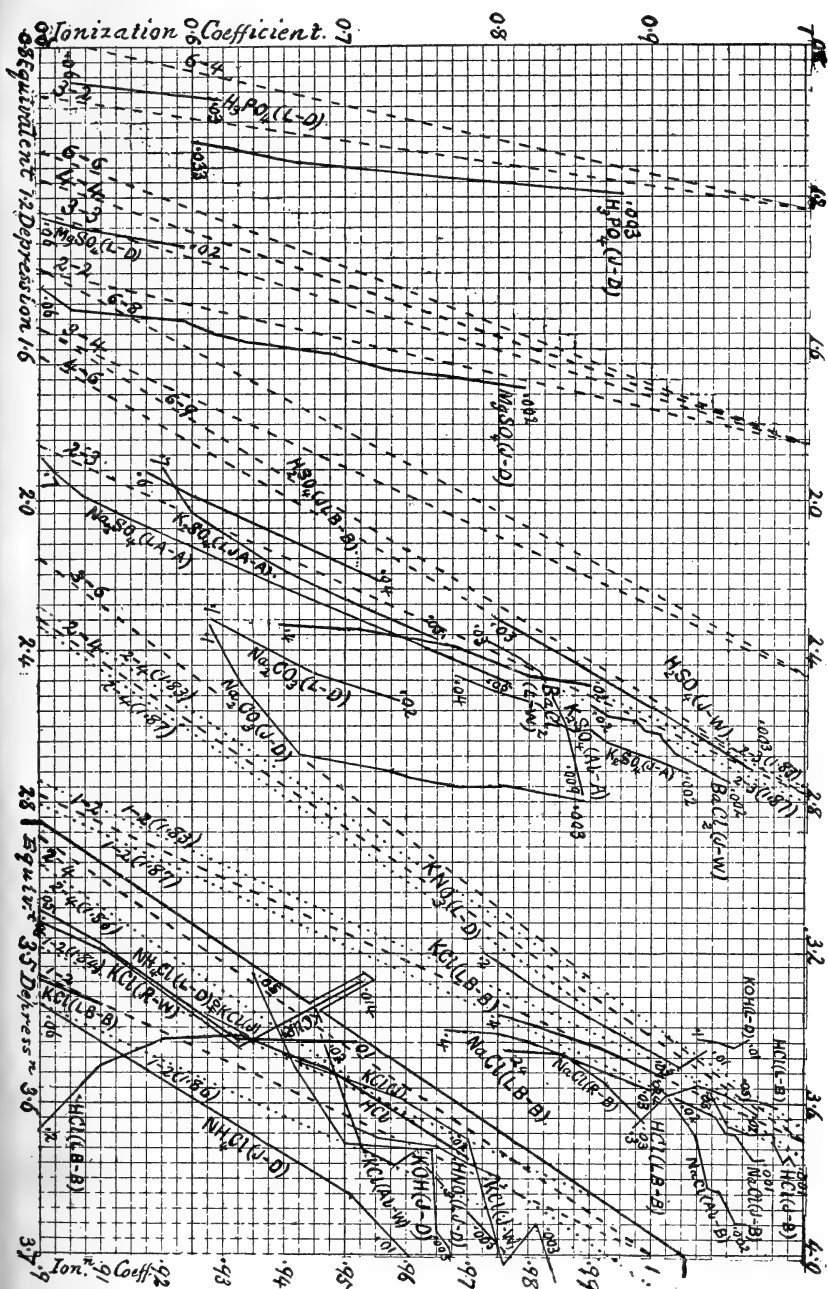
Loomis's curves bend towards the left, suggests that the actual curve after starting at the 2—3 intersection, may bend considerably to the right before association or change of mode of ionization has advanced sufficiently to change the direction of its curvature.

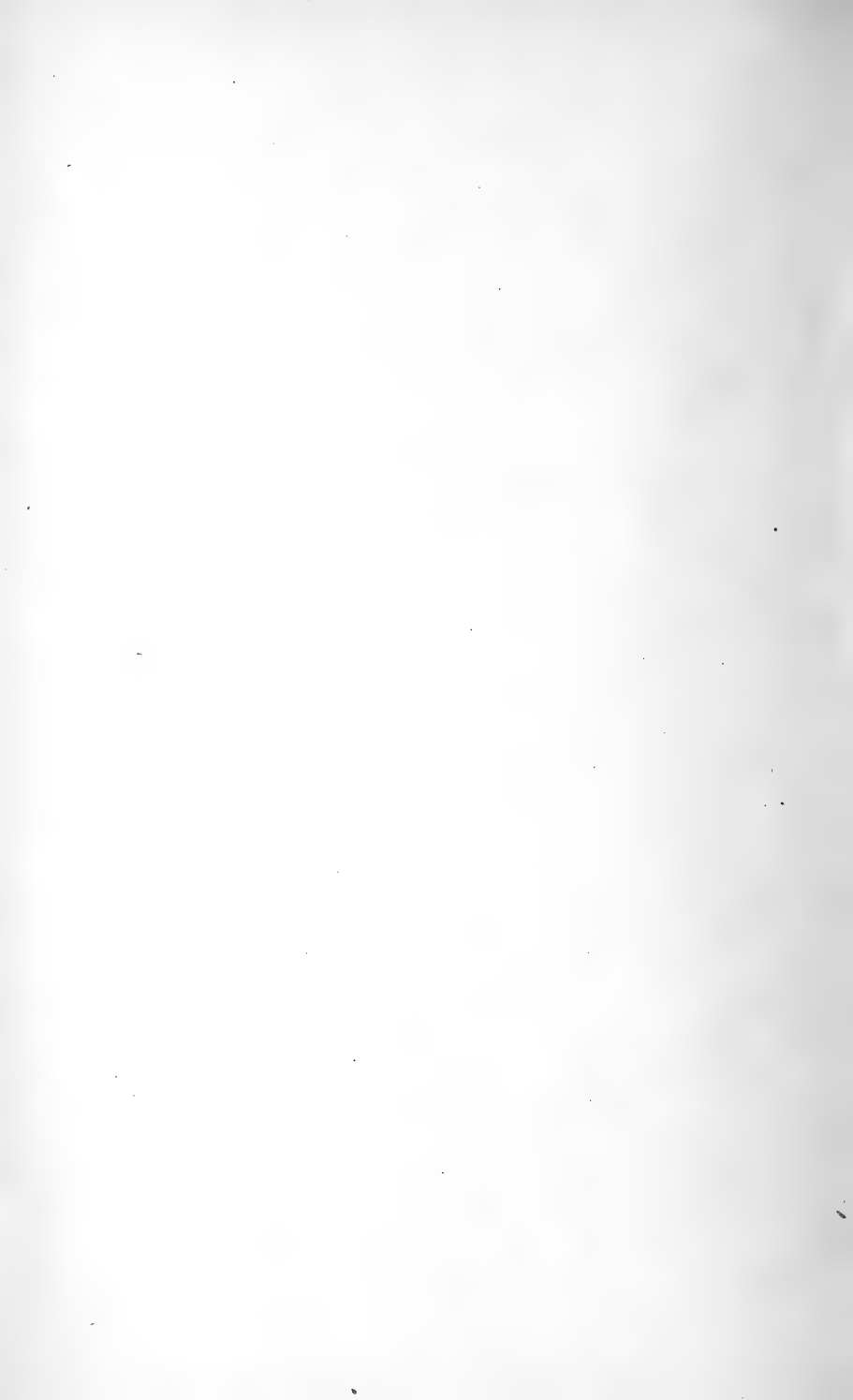
An electrolyte such as MgSO_4 , according as it may exist in solution in single, double or triple molecules, and according to its mode of ionization in associated molecules, may have a 2—2, 4—4 or 2, or 6—6, 4, 3 or 2 curve. Jones' curve lies to the right of the 2—2 (1.85) line, bending towards it, and may quite readily be a 2—2 (1.85) curve, changing to a 4—4 or 4—2 curve. Loomis's lies between the 2—2 and 4—4 lines. A mean curve would already, at a concentration .02, have crossed the 2—2 line. The data, such as they are, are consistent with the depression constant having a value of about 1.85, and would indicate single molecules in dilute solutions, doubling of molecules at a very early stage, and a steady increase in association throughout.

According as H_3PO_4 , if it exist in solution in single molecules, may dissociate into 4, 3 or 2 ions, will it have a 3—4, 3—3, or 3—2 curve. If it have double molecules, its curve may be a 6—8, 6—7, etc., to 6—2 curve, according to the mode of ionization. Jones' curve runs down to the right of the 3—2 (1.85) line, bending towards the line. Loomis's lies between the 3—2 and 6—4 lines. A mean curve would be just to the right of the 3—2 line, and might readily run out at the 3—2 (1.85) intersection. This would indicate single molecules in dilute solutions dissociating into two ions, an early occurrence of doubling of molecules, and steady increase in the extent of association as dilution diminished, the double molecules formed dissociating into 4, 3, or 2 ions, but not into more. Although the coefficients with which the curve is plotted are doubtful, the curve is so nearly parallel to the axis of ionization coefficients, that even a considerable error in their values would not affect the above conclusions.

General Conclusions.

Although the observations on which the above discussion is based are defective, and the particular conclusions drawn are consequently tentative, I think it may be held with some confidence (1) that the curves of equivalent depression against ionization coefficient, have positions, forms, and slopes, such as they might be expected to have, on reasonable assumptions as to mode of ionization and constitution in solution, according to the Van 't Hoff-Arrhenius theory of the depression of the freezing-point in solutions of electrolytes, (2) that for all the electrolytes examined, they are consistent with the depression constant having a common value of about 1.85, and that in the case of the electrolyte for which we have the best data, the curve is not consistent with a greater limit of error in this value than about .01, unless improbable assumptions are made with respect to the constitution of the electrolyte in solution, and (3) that the diagram enables us to reach in some cases, conclusions of considerable probability with respect to the constitution of the electrolyte in solution, and its mode of ionization.





VIII.—GEOLOGICAL NOMENCLATURE IN NOVA SCOTIA.—BY
HUGH FLETCHER, ESQ., B. A., *of the Geological Survey
of Canada.*

(Communicated on the 14th May, 1900.)

THE DEVONIAN.

In the summer of 1876, a great series of metamorphic rocks, cut by masses of granite and trap, was separated in Cape Breton from the overlying Carboniferous conglomerate made up of their detritus. These rocks were then traced from Loch Lomond to St. Peters, through Isle Madame and into Guysboro and Antigonish counties, as recorded in the reports of the Geological Survey between 1877 and 1881.

Localities were described at which the Carboniferous, comparatively unaltered, comes in contact with and contains pebbles of these metamorphic rocks; several sections indicating a thickness of at least 10,000 feet were given in detail and mention was made of carbonized plants, fish remains, ostracods and other fossils found in many of the beds, the plants including forms like *Psilophyton*, a characteristic Devonian genus.

Above them lies a formation, several thousands of feet in thickness, containing marine fossils of the Carboniferous Limestone series of England and characterized everywhere from Newfoundland to the western boundary of New Brunswick, a distance of 450 miles, by the occurrence of thick beds of gypsum; while at their base lie about 3,000 feet of limestones and other beds of marine origin, shown by Dr. Honeyman, in one of the finest pieces of combined stratigraphical and palæontological geology yet done in Nova Scotia, to range at Arasaig from Medina to Lower Helderberg.

Rocks in this position, precisely similar in lithological character, had been called Devonian in New Brunswick, Newfoundland, Gaspé and on Logan's map of the Pictou Coal field, and this name was accordingly applied to them in Cape Breton.

It was subsequently found that the large Pre-carboniferous area, eighteen miles wide at the Strait of Canso and five miles in width at Lochaber, thirty-five miles to the south-west, instead of being Silurian as claimed by Sir William Dawson, contains only these plant-bearing Devonian strata which are divisible into three groups corresponding closely with those into which the Devonian rocks of New Brunswick had already been subdivided. They extend from Lochaber along the East River of St. Mary's and the East River of Pictou to strike the Inter-colonial railway near Glengarry, form the high land south of Truro and pass unconformably beneath the Carboniferous of Stewiacke River; and a small area is found at MacAra Brook, from which come the fish remains and *Pterygotus* subsequently described by A. Smith Woodward as homotaxial with the upper Silurian or lower Devonian of England.

As this grouping affected also rocks referred by Sir William Dawson * on the evidence of their fossil plants "to the lower part of the coal formation or Millstone Grit" and even higher, it was naturally called in question; and in 1885 Mr. T. C. Weston was sent to Nova Scotia, assisted by Mr. J. A. Robert, to collect fossils between Riversdale and the Strait of Canso. They found everywhere *Lepidodendron corrugatum*, *Stigmaria ficoides* and *Cyclopteris acadica*, forms supposed to be characteristic of the Horton series; on the East River of St. Mary's plants which resemble rhizomes of *Psilophyton*; and, near Sunnybrae, Cordaites and numerous markings of *Psilophyton* allied to *P. glabrum* and *P. elegans*; at and near Riversdale they obtained *Calamites*, *Sphenopteris*, *Anthracomya elongata* and *A. laevis*, *Lepidodendron corrugatum*, *Stigmaria ficoides*, ferns and erect trees, characteristic again of the Horton series.

These rocks near Truro and on Cobequid Bay and Minas Basin had in the meantime been recognized by Dr. Ells as probably identical with the Devonian of New Brunswick.

* Acadian Geology, pages 485 and 489; Plants of the Lower Carboniferous and Millstone Grit, p. 13.

The Reports of the Geological Survey for 1885 and 1886 were sharply assailed by Sir J. W. Dawson for their disregard of fossils; they were assumed to cast doubt upon the value and accuracy of the work done in Cape Breton. "As to the rocks of the Riversdale section and that at MacKay Head, I have no hesitation in saying that it would be contrary to all analogy, not only in Nova Scotia but everywhere else, that they should be as low as the Horton series. They are unequivocally Millstone Grit and the flora of these sections is so well-known that there can scarcely be any mistake respecting it. The opinion advanced by Dr. Ells that the rocks of MacKay Head are like those of Riversdale is quite correct, they being the same series; but the comparison of them with the St. John Devonian is quite unwarrantable, the fossils being quite distinct."

This strong dissent induced Dr. Selwyn in 1892 to visit the region and see for himself the position of these strata. His view of their relations was emphatically expressed in the Summary Report for that year. In the conclusions arrived at by Mr. Fletcher he fully agreed. In 1895, Dr. Selwyn was succeeded as director of the Geological Survey by Dr. G. M. Dawson. Maps of Pictou and Colchester counties were then being engraved. The compilation of Sheets 43 to 48 was completed and that of Sheets 56 to 65, 76, 83, 100 and 101 well advanced. In the same year Dr. Ami was sent to Nova Scotia to obtain palæontological evidence of the age of the rocks in question; in the following seasons he was accompanied by the director, and in one season by Dr. Ells.

But in 1898 "certain points connected with the geological structure of that region remained still critical," although it was hoped that the special investigations of that year might render it possible to complete the information for several of the above sheets, which in that event would be promptly issued. At this time, Dr. Ami was protesting against the publication of a report in which he was represented as advocating the Carboniferous age of these rocks. On the contrary, he believed the evidence to show "that the strata of Union and Riversdale may be

regarded as equivalent to those in Lancaster township, New Brunswick, described and held to be of Devonian age," adding that several typical Horton fossils, such as *Lepidodendron corrugatum* and *Cyclopteris acadica* are common to the Riversdale and Union rocks and to the Devonian of New Brunswick.

In the following year, however, he states that so far as the faunas are concerned they clearly indicate a Carboniferous facies for the New Brunswick Devonian, the rocks of Harrington River, Parrsboro, Riversdale, Union and Horton Bluff. The only proof adduced for this radical change, and the addition of 15,000 feet of strata beneath the Limestone to the already enormously developed Carboniferous of Nova Scotia, is that of certain fossils, assumed to have a definite range, in regard to some of which he is surely mistaken. For "the protolimuloid crustacean, usually referred to the Carboniferous system" is on the contrary* also found associated with such characteristic Lower Devonian forms as *Pterygotus*, *Coccosteus*, *Pterichthys* and *Glyptolepis*; *Estheria* is not "all the world over recognized as Carboniferous" any more than *Pterinea* is peculiar to the Devonian; *Leania* occurs in Pennsylvania in rocks regarded by most geologists as Devonian; and Professor Marsh has described, from the Devonian, amphibians as highly developed as the *Dendrerpeton* found by Sir William Logan at Horton Bluff in 1841 and by Dr. Ami, at Parrsboro in 1898, the affinities of which the latter regards as Permian.

Collections of fossil plants from these rocks in Nova Scotia and New Brunswick were examined by Mr. David White of the United States Geological Survey in 1898, and by Mr. R. Kidston of Stirling, Scotland, in 1899, who came to almost the same conclusions on perfectly independent grounds. Their views are given at length by Dr. Whiteaves in his "Address on the Devonian System in Canada," and may be thus summarized: (1) The Horton series is nearly contemporaneous with the Pocono formation of the eastern United States and the lower

* Ottawa Naturalist for January, 1900, Vol. VIII, No. 10, p. 256.

Carboniferous of England. (2) The Riversdale and Harrington River series are assuredly newer than the Horton and have a most pronounced Upper Carboniferous facies. (3) The plant-bearing beds near St. John, N. B. are not Middle Devonian but Carboniferous and are the exact equivalents of the Riversdale series.

Dr. Whiteaves adds: "Our knowledge of the organic remains of the Devonian of Nova Scotia is still in its infancy, and it would seem that the plant-bearing beds near St. John, N. B., which have so long been regarded as Devonian, may possibly be Carboniferous."

Admitting apparently that "a classification by faunas alone is one-sided and that the physical history of the strata should also be considered," Dr. Ami, in 1899, set aside the authority of the palæontologists mentioned above and accepted the order of superposition* given by "the two geologists on the Canadian Survey staff, who have studied the question from a stratigraphical and lithological point of view," but, as a sort of compromise, for their name Devonian he substituted "Eo-Carboniferous," just as he had previously employed the word "Eo-Devonian" for the so-called Lower Oriskany of Nictaux. This stratigraphical sequence has indeed been admitted by all geologists who have examined it in the field. Richard Brown, Campbell, Gesner, Lyell, Honeyman, Logan, Poole, Ells, Fletcher, Selwyn and others in Nova Scotia; Gesner, Hartt, Matthew, Bailey and Ells in New Brunswick; Murray in Newfoundland; Ells and Whiteaves in Gaspé—all place these rocks beneath the Carboniferous Limestone, near the debatable line between Carboniferous and Devonian, in many indisputable sections where no thrust-faults, outliers, overturned fossil trees or other agency of theoretical biologists are available to make part Devonian, part Coal Measures.

It becomes, then, a question of the transference across this line not of a few feet of strata but of a system of 10,000 to 15,000 feet of beds cut off from a marine formation both above

* Ottawa Naturalist, Vol. XIII, No. 9, p. 207.

and below by great unconformities and intrusions of granitic rocks. The only evidence brought against the name Devonian is that of certain fossils assumed to have a definite range in geological time. Were such a means of classification possible in the present state of our knowledge, and we were to understand that, for example, rocks must not be called Devonian above the horizon of the appearance of amphibians, or Silurian above that of fishes, such a classification would be quite satisfactory. Palæontology is not, however, one of the mathematical or exact sciences, but has its limitations even in the countries in which it has been most diligently studied; consequently, uncertainty exists both in Europe and America regarding the proper limits of this and other formations. We have heard, for example, the work of the Second Geological Survey of Pennsylvania, a most important and thorough industrial investigation, described as conducted on the plan that correlations can best be made by lithological means. "Frequently one meets with expressions of lack of confidence in the evidence offered by fossils." And in a recent report on the Devonian and Carboniferous* "the whole subject of the value of fossil plants as means of correlation" is said to be "under consideration."

It is only necessary to read this report to realize the difficulty met with in attempting to group these rocks by their fossils in Pennsylvania, Ohio, Virginia, Illinois, Michigan and other states†—a difficulty well stated in a report of the American committee of the International Congress of Geologists‡ as follows: (1) "Shall we include the Catskill rocks (and, when no marine faunas occur, up to the base of the Olean conglomerate and equivalents) in the Devonian? (2) Shall the Chemung marine fauna be taken as the uppermost fauna of the Devonian? Or shall a part or the whole of the marine faunas between the middle Devonian and the conglomerate which introduces the Coal Measures be called Devonian? If an arbitrary line is to

* Bulletin of the U. S. Geol. Survey, No. 80, pp. 123, 208 and 228.

† Cf. also "Science" for 26th Jan. 1900, p. 140.

‡ Rep. Geol. Congress, 1888, A. pp. 102, 144; B. pp. 144, 153, 154, 156.

be drawn faunally it should be between the Chemung and the Waverley. The difficulties are not less serious in England, and the Pilton and Baggy beds hold faunas which it is as difficult to settle on the Devonian or Carboniferous side as it has been with the Waverley, Kinderhook or Marshall." Professor J. S. Newberry then proposes a classification in which he includes in the Carboniferous system all strata from the Permian to the Chemung, both inclusive ; whereas Professor Hall adopts the first alternative suggested above and restricts the term Catskill group to the beds known as X and XI of the Pennsylvania survey (Pocono and Mauch Chunk) ; and others speak of the latter as distinct from and overlying the Catskill. Adopting Professor Hall's grouping it would seem that the Mauch Chunk and Pocono may represent respectively the Union and Riversdale series of the Nova Scotian Devonian ; and that, unless the littoral and estuarine sediments of Pennsylvania represent the pelagic rocks of the east, there must be a great unconformity by which the gypsiferous formation, traced, as above stated, from Newfoundland to the Aroostook, is lost. It has been found that in working up from the lower Palæozoic, the fossils seem to carry the Catskill to XI of the Pennsylvania classification, in working downward from the upper Palæozoic, the fossils seem to carry the Permian to VIII (Venango).

The International Congress proposes to place the upper limit of the Devonian at the base of the Carboniferous Limestone and to include in the former the Catskill and the so-called Lower Carboniferous or Tweedian group of Scotland. The Tweedian has been also correlated with the Condruz beds of Belgium, from which one of the subdivisions of the Devonian (Condrusian) in the classification of the Congress takes its name.

The annexed tabular view of various classifications proposed for these rocks will show at once their radical inconsistency and the indefinite range of the fossils :—

1	2	3	4
CANADIAN GEOLOGICAL SURVEY.	ELLS & FLETCHER.	DAWSON IN NEW BRUNSW'K.	DAWSON IN NOVA SCOTIA.
CARBONIFEROUS SYSTEM.			
Permian.	Permian, or Upper Carboniferous.	Upper Carboniferous.	
Coal Measures.	Coal Measures.	Coal Measures.	Union or Salmon River.
Millstone Grit.	Millstone Grit.	Millstone Grit.	Riversdale.
Carboniferous Limestone.	Carboniferous Limestone.	Windsor Series.	Windsor Series (Upper Carboniferous of Schuchert.)
Carboniferous Conglomerate.	Carboniferous Conglomerate.	Horton Series or *Albert Shales.	Horton Tweedian of Scotland.†
DEVONIAN SYSTEM.			
Catskill.		Perry.	
Chemung.	Union, including rocks of MacAra Brook, Lochaber and Economy.	Mispec.	Logan's Devonian of Middle River of Pictou. Rocks of Brookfield.
Hamilton.	Riversdale, Harrington River (4000 ft). MacKay Head and Horton.†	Cordaite Shales Dadoxylon Sandstone.	
Corniferous.	Basal Conglomerate.	Bloomsbury.	
Oriskany.			
SILURIAN SYSTEM.		Dr. G. F. Matthew suggests placing the Cordaite Shales in the Silurian.	

* An unconformable series beneath the lower carboniferous limestone and conglomerate.

† The relation of the Horton to the beds immediately overlying the Silurian has not yet been worked out.

5 R. KIDSTON.	6 DAVID WHITE.	7 PENNSYLVANIA.	8 JAMES HALL.	9 J.S. NEWBERRY.
Union ?				Permian.
Riversdale, Harrington River, and Cordaite Shales (St. John Devonian).	Union			Coal Measures.
	Riversdale and Cordaite Shales (Devonian of St. John, N. B.)	Pottsville XII (Olean.)		Millstone Grit.
		Mauch Chunk XI.		Carboniferous Limestone.
Horton — (Lower Carboniferous of England).‡	Horton (Pocono of Pennsylvania, Waverly. Newer than Kiltorcan).	Pocono X (White Catskill of Lesley).		Waverley.
		Catskill IX.	Mauch Chunk XI. Pocono X.	Catskill.
		Chemung VIII (Venango).		Chemung.
				DEVONIAN SYSTEM.
				Hamilton.
				Corniferous.
				Oriskany.
				SILURIAN SYSTEM.

‡ Referred by the International Congress of Geologists to the Devonian (Condrusian).

Only the knowledge that palæontologists sometimes "give more consideration to the results of theoretic biologic studies than to the already established stratigraphic succession of the faunas" can explain the foregoing table, which offers the alternative of correlating with the Nova Scotian productive coal measures, lying thousands of feet above the Riversdale, either the Coal Measures of England or the Cretaceous coal-bearing rocks of the Pacific coast.

The Horton cannot be at the same time above and below and on the same horizon as the Riversdale; and Dr. Ami has perhaps acted wisely in omitting it from his classification, its prominence in the others being due to its being easily accessible and first examined. At Horton Bluff it contains only 287 feet of strata well exposed on one side of a syncline, and 459 feet, not so well exposed, on the other; whereas the section at Harrington River shows nearly 4000 feet of black and gray beds; that near Union station 6468 feet of red beds of the upper * group alone (of which 684 feet, containing fish remains throughout, were remeasured at MacAra Brook); while a great thickness of the lower gray and black beds is exposed along the railway from Riversdale to West River and in every brook flowing south from the Cobequid Hills, these exposures being sometimes almost continuous for several miles, as recorded in the reports of the Geological Survey.

It will be readily understood that fossils thus studied and applied, having fixed no definite horizon higher than the Lower Helderberg, have hindered not helped in mapping the comparatively simple geological structure of these formations, while most satisfactory progress has been made by Mr. Fairbault in an investigation of 27,000 feet of more complicated, non-fossiliferous rocks comprising the gold-bearing series of the province.

* Geol. Survey Report for 1886, Part P, page 65.

IX.—NOTES ON A CAPE BRETON MINERAL CONTAINING TUNGSTEN, AND ON THE EFFECT OF WASHING CERTAIN CAPE BRETON COALS.—BY HENRY S. POOLE, F. G. S., F. R. S. C., *Assoc. Roy. Sch. Mines, etc., Stellarton, N. S.*

(Read April 14th, 1900.)

In the last issue of the Transactions of this Institute there was published a paper read March 13th, 1899, entitled "New Mineral Discoveries in Nova Scotia." The paper made reference to the finding at North East Margaree, C. B., of a mineral containing tungsten and speaks of it as Wolframite with 67.47 per cent. of $W O_3$, but makes no note of its other constituents. A month later, at a meeting of the Mining Society, Mr. A. C. Ross read a paper on the same mineral, and in the discussion which followed an analysis made by Mr. Mason, the assayer at Halifax, was given by Mr. Missener. This analysis,* of concentrated ore, showed but a trace of iron, and was as follows :—

Tungsten Trioxide.....	66.32
Silica	6.25
Manganese.....	12.02
Iron.....	.12
	<hr/>
	84.71

* The following letter from Mr. Mason gives additional information about this analysis :—

Halifax, Nova Scotia, April 23rd, 1900.

MY DEAR MR. POOLE :

The analysis was made for commercial purposes, not for scientific ones. However, being of a curious turn of mind I am able to give you some further information, although unfortunately only qualitative, not quantitative. A close inspection of the mineral (I fancy I gave you a sample) will I think reveal that it is composed of Quartz and Hübnerite principally, but there is also a little Scheelite. With regard to the missing 15 per cent., the Manganese is reported as metal. I fancy it exists in the mineral as $Mn_3 O_4$, and if so, that accounts for a difference of about 4.5%. The balance was made up of mixed oxides of Niobium and Tantalum, and also of Lime. Whether the lime all belongs to the scheelite or whether part of it should join the quartz as gangue, I did not determine. I regret that I have mislaid the memo. of the quantities. I did not discover that the mineral also contained Scheelite until I panned some of it, but afterwards clearly detected it in some samples but could not find it in others.

Yours very truly,

F. H. MASON

The absence of iron and the comparatively large amount of Manganese in the composition of this mineral would class it as more nearly allied to Hübnerite than to Wolframite.

In the same paper reference is made to the beneficial effects from washing certain Cape Breton coals, whereby the quantity of Sulphur ordinarily contained in coal as supplied from the slack heaps is greatly reduced, and the resulting Coke is made suitable for Iron smelting. The experience at the Ferrona furnace is spoken of, but as the reference to the operations at that furnace are somewhat incomplete, the following data supplied by the Manager, Mr. J. D. Fraser, will doubtless on comparison prove of interest. A test made in September and October, 1895, with fifty-ton samples from each of the following Mines, gave as follows:—

	RAW COAL.		WASHED COAL.	
	Ash.	Sulphur..	Ash.	Sulphur.
Hub.	7.50%	3.24%	4.37 %	2.38%
Caledonia ..	15.00 "	3.02 "	7.05 "	2.87 "
Stirling	11.09 "	4.23 "	5.50 "	3.12 "
Gowrie	11.55 "	5.26 "	6.01 "	3.15 "

D. HERTING, *Chemist*.

A test of 10,000 tons of small coal in December, 1897, and January, 1898, received from the Dominion Coal Company, gave the following average results:—

	RAW COAL.	WASHED COAL.
Moisture.	2.10 %	1.97 %
Volatile Combustible Matter.	31.00 "	33.21 "
Fixed Carbon.	56.83 "	60.00 "
Ash.	10.07 "	4.82 "
Sulphur.....	2.38 "	1.79 "

Coke made from this washed coal analysed:—

Ash.	9.16 %
Volatile Combustible Matter	1.86 "
Fixed Carbon	88.98 "
Sulphur	1.62 "

I. MACFARLAN, *Chemist*.

For comparison with the work done in the coal washer, a laboratory test was made. An average sample of the coal was treated in a solution of Calcium Chloride of 1.40 Sp. Gr., the coal of 1.30 Sp. Gr. floated on the solution, and the shale of 2.04 Sp. Gr. sank to the bottom. Thus separated, the coal and shale were thoroughly washed and dried, and severally bore to the unwashed material the following proportion:—

Coal.	81 %
Shale, etc.	90 "

Dried at 212° Fahr. they yielded on analysis:—

	RAW COAL.	WASHED COAL.	SHALE.
Volatile Combustible Matter.	33.06 %	33.79 %	31.43 %
Fixed Carbon	55.93 "	61.33 "	15.33 "
Ash	11.01 "	2.89 "	48.08 "
Sulphur	2.41 "	1.64 "	5.16 "

The same Coal treated in the coal washer yielded:—

	RAW COAL.	WASHED COAL.	SHALE.
Volatile Combustible Matter.	33.06 %	34.07 %	30.82 %
Fixed Carbon	55.93 "	61.26 "	23.21 "
Ash	11.01 "	4.67 "	41.22 "
Sulphur	2.41 "	1.70 "	4.48 "

On coking, 204 ovens made 683 tons of coke which showed an average composition as follows, after being dried at 212° F. :—

Moisture	0.40	
Volatile Combustible Matter	1.60	
Fixed Carbon	89.82	
Sulphur	1.65	
Silica	3.52	
Metallic iron	1.71	
Alumina .....	.46	
Manganese .....	.03	
Lime .....	.82	
Magnesia .....	.16	
Phosphorus. ....	.02	
		Ash 8.18 %

Available Carbon, 87.02.

X.—MINERALS FOR THE PARIS EXHIBITION.—BY E. GILPIN, JR.,
LL. D., F. R. S. C., *Inspector of Mines.*

(Communicated 12th February, 1900.)

The Government of Nova Scotia having decided to assist the Canadian Geological Survey in the preparation of the Canadian Mineral Exhibit at the Paris Exhibition, the work of collection was assigned to the Mines Office. In the process of collection opportunity has been afforded of procuring some interesting information. I do not contemplate giving a detailed account of each mineral locality represented, as that would occupy an undue space in the Transactions, but will confine myself more especially to those exhibits which were accompanied by descriptive matter, analyses, etc. It may be remarked that no trouble has been spared by the Survey to make the mineral exhibit a leading feature of the Canadian representation at Paris, so that all the mining districts will undoubtedly receive a most important and valuable advertisement. It is to be regretted that so many mining men have neglected the opportunity offered of presenting not only their own operations, but also those of their country to the gaze of the world. At no time has there been on the continent of Europe so marked a difficulty in procuring the raw material, and the unworked metals, and there is also a great demand for opportunities for investment of capital. This interest is not confined to the precious metals, but extends to every mineral that can be utilized in the arts. In many cases, the Department, instead of receiving samples from mine owners only too pleased to have their products exhibited, was obliged to send to the quarries, etc., and procure specimens, while the owners showed no interest whatever. Paternalism may be good, but the individual should show an interest in his own welfare.

Coal.

As would be expected the coal fields are well represented. The Springhill coals were shown in their different forms as

presented for consumption. These coals are largely used for steam purposes, especially in locomotives, they are also good coking and domestic coals. In recent communications to the Institute I have given a number of analyses of these coals, showing the increase of their steam values, etc., as they have been followed to the dip.

The Dominion Coal Company exhibited the various forms of round, run of mine, slack, pea, nut coals, etc., required by the trade. This company also presented a column of coal, a section of the Phalen seam, which attains a thickness of nine feet. This column is to stand by a similar one from British Columbia, an illustration of the resources of Canada on the Pacific and on the Atlantic. In my last paper I drew attention to the interesting diminution in ash and sulphur in the Phalen seam as it was followed away from its outcrop. I also gave a summary of the tests of coal made at Glassport, Pa., U. S. A. I now give, as an interesting comparison, the results of similar tests of the Phalen and Hub seams made at the Solway ovens, in Syracuse, New York, U. S. A. Owing to rainy weather the car loads were saturated with moisture. Allowing for the moisture the sample of the Phalen seam weighed 405 tons, and that from the Hub seam weighed 307 tons. There were obtained from these coals respectively 302 tons, 74.68 per cent; and 224.74 tons, 72.37 per cent, of dry coke and breeze.

The Phalen seam yielded 11,012 cubic feet of gas per long ton. Of the gas 55.47 per cent was used under the ovens. The average calorific power of the gas was 571.85 B. T. U. The average illuminating value of the gas, with a fishtail burner was 9.9 candle power, with a Welsbach burner, 54.34 candle power.

The following is the average analysis of the gas:—

Carbon dioxide....	2.7 per cent.	Marsh gas	32.3 per cent.
Illuminants.....	2.9 "	Hydrogen	51.1 "
Oxygen .....	.13 "	Nitrogen	5.07 "
Carbon monoxide..	5.8 "		
		Total.....	100.0

The Hub seam yielded 10,539 cubic feet of gas per long ton, of which 55.46 per cent was used under the ovens. The average calorific power of the gas was 576.54 B. T. U. The average illuminating value of the gas with a fishtail burner was 9.8 candle power, with a Welsbach burner 54. candle power.

The average analysis of the gas was as follows :—

Carbon dioxide	3.1 per cent.	Hydrogen	50.7 per cent.
Illuminants	2.7 “	Marsh gas	30.9 “
Oxygen . . . . .	.2 “	Nitrogen	5.0 “
Carbon monoxide	7.4 “		
		Total	100.0

The Phalen seam yielded per ton 32.91 lbs. of ammonium sulphate, and the yield from the Hub seam was 32.24 lbs. In commercial estimates a deduction of from 5 to 10 per cent should be made for loss of ammonia during the process of concentration.

The Phalen seam yielded per ton 12.89 gals. of tar, 128.9 lbs., and the Hub seam yielded 13.89 gals. of tar, 138.9 lbs. The Phalen seam yielded .103, and the Hub seam .111 gals. of benzole.

In considering the illuminating power and composition of the gases given above it must be remembered that they are averages. It was pointed out in my last paper that the gas obtained from the first portion of the period of coking is much higher in illuminating power, etc., than that given off during the latter portion of the period of coking.

The General Mining Association. — This company has a large number of valuable coal seams, but has hitherto confined its operations to one, known as the Sydney Main Seam. This seam has been worked for over one hundred years, and still remains one of the most valuable assets of the Province. The average thickness of the seam is five feet two inches. The annual output 271,000 tons. The portion of the seam now being worked is entirely under the Atlantic Ocean, the samples exhibited being taken from a point 2,200 yards from the nearest land, and at a depth of 1,000 feet below the bottom of the ocean.

The following analyses made at different periods will show the general uniformity of the seam :

(1871.) *Analysis by Dr. How.*

Moisture	3.04	Average Coke	70.30
Volatile Combust. Matter.	31.14	Theoretical Evapora-	
Fixed Carbon	61.50	tive power	9.06 lbs.
Ash	4.32	Sulphur	1.24
		Specific Gravity	1.30
	100.00		

(1890.) *Analysis by the Writer.*

	Slow Coking.	Fast Coking.
Moisture .....	.420	.420
Volatile Combustible Matter.....	34.962	37.110
Fixed Carbon	59.993	57.845
Ash	4.625	4.625
	100.000	100.000
Sulphur .....	.95	.95

(1891.) *Average Samples from Five Sections of the Mine.*

Moisture	1.536	Fixed Carbon	57.008
Volatile Combustible		Ash.....	5.084
Matter	36.372	Sulphur.....	1.894

Of the underlying seams in the North Sydney district, not much can yet be said. The General Mining Association has recently proved them by a shaft to the fourth seam. These seams are of good quality, and from three to four feet thick. I append an analysis of the third seam, made a few years ago, from samples taken from the openings of the North Sydney Mining Company, along its outcrop :—

Moisture	2.06	Ash	7.46
Volatile Combustible			
Matter	30.16		100.00
Fixed Carbon	60.32	Sulphur .....	.84

These seams are now receiving attention at the hands of the Sydney Coal Company, and, although thinner than the main seam, will undoubtedly in the near future prove valuable from their uniformity and proximity to deep water.

The coals of Pictou County are represented by samples from the mines of the Acadia Coal Company. These deposits have long been worked. Samples of coal are also shown from the Chignecto, Joggins and Springhill Collieries. Interesting analyses, etc., of the seams found at the last-named district have been furnished by me in late numbers of the Transactions of the Institute.

Manganese.

At present the production of manganese is at a low ebb in this province. For many years the Tenny Cape Mines had a world-wide reputation for the production of small amounts of extremely pure ore. For some time past little ore has been mined. It is not doubted that the resources of the district are exhausted; but the researches of the chemist have pointed out methods for the production of pure manganese oxide as a by product, which have lessened the demand for a native ore almost chemically pure. However the demand for manganese for steel making purposes has again offered a market for manganese ores, high in grade, and phosphorus free. Attention is now being directed to the ores of this district, and with modern appliances for prospecting and mining it is anticipated that Tenny Cape will again become a producer. The samples collected exhibit well the celebrated crystalline pyrolusite characterising the district.

The following analysis will serve to show the character of the ores of this district, which occur in lower carboniferous limestones:—

	I.	II.
Moisture	1.66	2.05
Water of Composition.....	3.63	....
Iron peroxide .....	.603	2.55
Oxygen	7.036	....
Baryta .....	.724	1.12
Insoluble	1.728	2.80
Phosphoric acid .....	....	1.029
Manganese oxides	84.620	....
Peroxide of manganese .....	....	90.15
Lime.....	....	trace.

Ores less crystalline but equally pure occur at Loch Lomond in Cape Breton County, at the Moseley Mines. The ore is found in both the crystalline and amorphous forms in a red shale of lower carboniferous age about five feet thick. It is presented as layers and beds from one to eighteen inches in thickness. The enclosing material being soft it is readily extracted. The position of the mine has necessitated unfavorable conditions for shipment, but the construction of the railway now under contract between the Strait of Canso and Louisburg will furnish a ready access to admirable shipping facilities.

The following analyses will serve to show its quality :—

	I.	II.	III.
Peroxide of manganese (available).....	91.84	87.64	92.65
Peroxide of iron.....	12	trace.	4.14
Insoluble.....	2.71	8.51	trace.

The ores of this metal occur in workable amounts in Onslow, near Truro, as veins, and in the partings of the lower carboniferous sandstones.

During the past few months New Ross, in the northern part of Lunenburg County, has promised to become a producer of manganese ores. Miner T. Foster has opened a number of veins which are of high grade, and available for economic extraction. A few tons have been shipped, and have found a ready sale. The extent of the manganiferous ground, and the age of the strata holding the ores, has, I believe, not yet been worked out. Explorations made during the past season, have shown that the Dean and Chapter lands adjoining the Foster properties contain, at several points, deposits which promise to be valuable. The ores of this district have, so far as I can learn, not been exhaustively analysed. They contain, however, manganese in amount suitable for steel and chemical purposes.

The Mineral Products Company of Bridgeville, Pictou County, also exhibit samples of manganite, and of manganiferous limonite. It is reported that recent developments in the iron ore mines of this locality have shown the presence of considerable amounts of the latter mineral.

Gold Ores.

The collection of gold specimens procured for the exhibition although not as rich as could be desired, may be termed representative of a number of the best known districts. I will refer briefly to the districts represented. The department contributed a set of Montagu specimens, valued at \$1,200.00, at present on exhibition at the Imperial Institute, London, also specimens from Renfrew, Mt. Uniacke, and Waverly. Another handsome set, approaching in value that first named, was secured from Messrs. Jack & Bell. Another sample was from the famous "Plough Lead" at Isaacs Harbor.

The following parties also contributed samples, some of which were very handsome, accompanied by samples of concentrates, wall rocks, photos, etc.:

J. J. Withrow	South Uniacke.....	Gold-bearing quartz.
"	"	Concentrates.
J. Hirschfield	Goldenville	"
Guffey Jennings	Caribou	Gold-bearing quartz.
W. C. Sarre	Cow Bay	"
Cashon & Hines	Leipsigate	"
"	"	Concentrates.
Elk Mining Co.	Caribou	Gold-bearing quartz.
"	"	Concentrates.
Montreal & London Gold		
Dev. Co.	Salmon River	Gold-bearing quartz.
Gue & Wilson	Waverley	"
R. R. McLeod	Malaga	"
J. H. Townsend	Lawrencetown	"
"	"	"
"	"	Wall rocks, etc.
W. L. Libbey	N. Brookfield	Gold-bearing quartz.
"	"	Wall rocks.
"	"	Concentrates.

Note.—At this mine there is a successful chlorination plan, the first in the Province.

J. D. Huntingdon.....	Yarmouth.....	Gold-bearing quartz.
“	“	Concentrates.
W. C. Anderson.....	Montagu.....	Gold-bearing quartz.
Jack & Bell.....	“	“
Cunningham & Curren.	Mount Uniacke.....	“
“	“	Concentrates.
J. D. McGregor.....	Fifteen Mile Stream.	Gold-bearing quartz.

Lead.

As yet the development of our lead ores has not reached the productive stage.

In Inverness County, in Laurentian felsites, at many points, are visible the effects of solfataric action, in deposits of copper, lead and zinc ores, often noticeably enriched with gold and silver. Some measure of development has been attained at Cheticamp by Halifax capitalists, who have opened a promising silver lead deposit. It is expected that these ores will be shipped to the smelter at Pictou, or to Swansea. Openings show the deposit to be from 3 to 10 feet thick, and to continue for several hundred feet. Roughly speaking, the ore carries one ounce of silver for each unit of lead, some samples showing as high as 78 per cent. of lead and 80 ounces of silver. Gold also shows in quantities varying from 3 to 14 dwts. per ton of 2,000 lbs. Similar results in gold and silver have been obtained from the Silver Cliff deposits and from zinc blende deposits in the same locality.

As yet the auriferous alluvium in the Cheticamp River has not received systematic attention. If there are gravels in the river worth working, they will be found where the river leaves the mountain, and not in its narrow gorges subject to frequent and severe freshets. No free gold veins have yet been reported, and the alluvial gold which attracted so much attention some time ago is probably derived from the felsites, which are reported to occasionally show fine flakes of gold.

At Red Head, a few miles to the north, some development work has been done on copper deposits, also auriferous. Galena

ore running high in lead and silver occurs at Caledonia, Guysboro County, and at Smithfield, Hants County.

Graphite.

The upper or slate division of the Nova Scotia gold fields frequently shows beds highly carbonaceous, but I am not aware that they have been practically tested. In the precambrian felsites and gneisses of Cape Breton, plumbaginous slates are not uncommon. Samples have been secured from the River Dennys district, and from the vicinity of the Grand Narrows. The rock from the latter locality yielded to the analyst of the Geological Survey :

Graphite Carbon	50.23
Rock matter	43.27
Water	6.50
	<hr/>
	100.00

Copper.

An interesting set of specimens and photos show the development work of the Cape Breton Copper Company at Coxheath, Cape Breton County. Here a number of deposits have been traced for several thousand feet, and proved to depths upwards of 300 feet. The deposits vary in thickness up to 12 feet, and may, so far as exploration work has been carried, be described as very long lenses, bedded in precambrian felsites and slates.

While some of the lenses carry copper contents up to 10 per cent., the ore will presumably belong to the class requiring concentration. Working tests have shown that concentration readily presents a suitable furnace material, unusually free from injurious ingredients. The following tables of analyses and of working tests of concentration are of interest :

CAPE BRETON COPPER COMPANY, (LIMITED), NOVA SCOTIA, CANADA.

Analyses of Cocheath Copper Ores. *Gold and Silver Assays.*

	LUCIUS PITKIN, New York.	FRED CLAUDET, London.	PROF. HOFMAN, Boston.	DR. EDW. D. PETERS, JR., Boston.			Copper.	Gold.	Silver.
				13.4	5.3	3.14			
Copper	6.04	8.99	6.79	13.62	9.84	7.18	29.6	0.17	0.45
Iron	14.11	12.83	15.79	18.1	11.13	8.64	17.	0.195	2.07
Sulphur	10.69	13.40	8.10	52.7	69.8	73.64	18.4	0.15	4.5
Silica	46.23	61.63	47.47	.....	.....	.....	25.2	0.26	3.5
Arsenic.	0.01	0.05	0.012	.....	.....	.....	15.7	0.15	4.5
Antimony	0.17	traces.	none.	.....	.....	.....	8.52	0.06	0.22
Lime.....	2.34	1.05	trace.	.....	.....	.....	6.89	0.05	0.40
Magnesia	2.27	0.32	3.88	.....	.....	.....	Concen- trates.		
Alumina	11.83	0.94	8.02	.....	.....	.....	7.23	0.7	
Cobalt .....	.....	0.06	.....	.....	.....	.....	9.50	0.3	
Lead	none.	.....	.....	.....	.....	.....	12.61	0.5	
Bismuth	0.001	.....	.....	.....	.....	.....	Tailings.		
Zinc	none.	.....	.....	.....	.....	.....	1.90	0.025	
Nickel	0.36	.....	.....	.....	.....	.....	2.05	0.01	
Phosphates. ...	0.08	.....	.....	.....	.....	.....	3.	Slimes.	
Oxygen & loss. ....	.....	.73	.....	.....	.....	.....		0.02	

DESIGNATION.	PYRITES.				MIXED PRODUCTS.				WASTE.					
	No. of sample.		Cu.		H 20.		Dry Weight.		Wet Weight.		H 20.		Dry Weight.	
	Wet Weight.	Ko.	%	Ko.	%	Ko.	%	Ko.	%	Ko.	%	Ko.	%	
Raw Ore, stated weight..	26	3551	0.23	3543	2.26									
Grains from :														
8-5-6 mm.	27			17.4	8.18	36		443	4.0	425				
" 5-6-4 "	28			25.4	8.15	37		680	4.0	657				
" 4-2-8 "	29			36.5	8.10	38		821	3.8	790				
" 2-8-2 "	30			10.4		39		341	7.5	316				
" 2-1-4 "	31			34.3	8.70	40		566	14.0	487				
Schlich from :														
Jigger under ½ mm.	32	175	14.4	149.8	9.78	41		283	18.0	232				
Schlich I. Iron pyrites	33			8	2.30									
from Rittinger														
Schlich II. Copper py-														
rites from Rittinger...	34	45.5	18.4	37.1	14.10	42		156	25.0	117				
Schlich from turning														
table	35	50.4	20.4	40.1	9.87	43		62.5	25.0	47				
Schamm from labyrinth														
(flour)						44		218	31.4	150				
Schamm from Clarifica-														
tion pit:						52		34	3.0	33				
Remains not treated														
				362						579				
Returns				10.217%						16.34%				

In regular work there will be obtained from the 579 Klg. mixed products still about 60 Kos. Schlichs, so that the total yield would amount to 11,85%.

Concentration trials en Coxheath Ore, by
Humboldt Works, Kalk, Germany.

Samples of similar ores are shown from St. George's River, Eagle Head and French Road, in the same County.

In Antigonish County the traces of copper ore are wide spread. At some points prospecting work has given promising results, but as yet the various licenses to search have received little attention.

A sample of copper ore from St. Joseph's is from a bed of mixed chalcopyrite and shale in lower carboniferous strata close to their junction with precarboniferous rocks, presumably of lower silurian age. There are about eight beds, reported to be from two to six feet in width. The following analysis of a sample from the No. 2 vein is by the Geological Survey Department:

Copper.....	27.00	Moisture.....	.20
Iron	29.70	Carbonate of Iron.....	6.20
Sulphur.....	33.50		—
Silica	3.40		100.00

At Polson's Lake somewhat extensive development work has shown, in Devonian strata, beside a dioritic dyke, a large mass of carbonate of iron and calc spar carrying copper pyrites. The ore is stated to average from 9 to 16 per cent. of copper, and to carry several dollars' worth of gold and silver. On the opposite or west side of the Lochaber lake, similar but richer ores occur in numerous veins with spar and specular iron. Exploratory work done here a number of years ago was fairly promising.

In addition to these deposits, carbonates, sulphides and silicates of copper are not uncommon in the carboniferous shales and sandstones in irregular masses, frequently rich, but limited in extent. Further work may, however, show localities where this class of deposits will reach economic values.

In Pictou County similar ores occur at a number of places in the permo-carboniferous and in the millstone grit and lower carboniferous. Traces of copper sulphide also occur in the district forming the water shed between the Bay of Fundy and

the Strait of Northumberland. The deposits near Pictou and River John have received some attention and will probably prove sources of this metal. At Dalhousie Mountain a good deal of surface exploration has been done on a vein from 2 to 3 feet wide carrying copper pyrites. Samples have shown up to 15 per cent. of copper and about \$26.00 of gold per ton.

It may be anticipated that where the Devonian strata of this district are intersected by dioritic and granitic dykes opportunity will be afforded for copper ores, in some cases, of commercial value. The rocks referred to appear again in the southern part of New Annan, and indications of copper ore are wide spread in quartzites and felsites associated with dioritic dykes, etc.

Developments have been made at New Annan, on the East Branch of the French River, about five miles from Tatamagouche Station. The property being developed presents a bed about four feet thick, carrying stringers of black sulphide and carbonate with nodules of various copper sulphides in a fine sandstone conglomerate resting on a blue clay floor. Similar deposits also occur at the Palmer mine, near Wentworth. Here the bed is about ten feet thick and much mixed with clay. The quality of these ores varies very much, according to the state of concentration reached in the process of formation. Samples can be had running up to 50 per cent of copper, with gold and silver in varying amounts. It is expected that these deposits and others of a similar character scattered from Amherst to Pictou will furnish material for the smelter at Pictou. More extended development will be required to determine this point. It is, however, extremely probably that the older rocks lying to the south of the carboniferous will yield deposits of ore larger and more uniform in quality.

Copper pyrites also occurs on the Portapique River, Colchester Co., in a stratum, presumably of Devonian age, over a tract several hundred feet wide and a mile in length. Samples show up to 20 per cent. copper, with traces of gold.

Iron.

Among the most interesting of the exhibits under this head is that of the Nova Scotia Steel Company. This company is an example of the successful progress of enterprise combined with commercial and technical skill. The forge works of New Glasgow, which acquired well-deserved notice for their work in ship frames, shafts, stems, etc., gradually grew and prospered. With the iron ores and coal of Pictou County at the doors of New Glasgow, it needed one step and the company produced its own raw material. A railway was built from Hopewell to the head of the East River, to open the Bridgeville iron ores and limestones. A furnace was built at the junction of the East and West branches of the East River, and a large steel works made Trenton another New Glasgow.

This measure of progress has not limited the company's ambition. By a lucky stroke of business they acquired possession of an enormous iron ore deposit on the coast of Newfoundland. This deposit was capable of yielding at the cheapest rate an ore suitable for the basic process. Accordingly large amounts have been annually imported for mixture with the limonite ores of Bridgeville. Exports have also been made to the United States and Europe. The company has sold part of this deposit to the Dominion Iron and Steel Company, it is said, for the sum of \$1,000,000.00. Now they propose to absorb the 22 square miles of coal area of the General Mining Association and to erect at North Sydney a steel plant rivaling that of the Dominion Steel Company.

The ores of the Pictou iron field comprise limonites, red hematites, and spathic and specular ores. As yet operations have been confined to the limonites mined by the Steel Co. There are enormous deposits of red hematites and specular ores yet untouched, and affording material for the establishment of an iron industry surpassing that contemplated at the Sydneys.

The samples exhibited by the company comprise ores, fluxes, fuels, pig iron, and the steel products.

The transactions of the Nova Scotia Mining Institute contain a full description of the plant of this company. The following analyses are self-explanatory :

Nova Scotia Steel Company, Trenton and Ferrona.

Iron Ores.

Red Hematite from Wakana Mine, Newfoundland, owned by N. S. Steel Co. Average analysis for year 1898 at 150,000 tons. Dried at 212° F. Moisture, 0.66.

Loss on ignition....	2.08 p. c.	Phos-Acid	1.62 p. c.
Silica	11.57 "	Sulphuric Acid.....	0.07 "
Iron Oxide	77.67 "	Titanic Acid.....	0.25 "
Manganese Oxide....	0.08 "	Metallic Iron.....	54.37 "
Alumina.....	4.55 "	Phosphorus.....	0.71 "
Lime (CaO.).....	1.81 "	Sulphur.....	0.03 "
Magnesia.....	0.44 "		

Magnetic Iron ore from Cuba, dried at 212 F. Average analysis :

Silica	9.91 p. c.	Manganese	0.41 p. c.
Alumina.....	0.85 "	Metallic Iron.....	61.02 "
Lime	0.50 "	Phosphorus.....	0.04 "
Magnesia	0.32 "	Sulphur.....	0.087 "

Red Hematite. (High phosphorus.) Torbrook, N. S.:

Silica	13.00 p. c.	Titanium	Trace.
Ferric Oxide	77.60 "	Barium Oxide	"
Alumina.....	4.28 "	Volatile matter.....	Nil.
Manganese Dioxide..	0.38 "	Carbonic Oxide.....	"
Calcium Oxide	1.90 "	Phosphorus.....	1.21 p. c.
Magnesium Oxide ...	0.35 "		

Limonite Iron ore, washed sample, from East River, Pictou. Average analysis :

Comb. water.....	12.40 p. c.	Magnesia	0.16 p. c.
Silica	11.25 "	Manganese.....	0.33 "
Ferric Oxides.....	73.23 "	Phosphorus.....	0.032 "
Alumina.....	1.49 "	Sulphur.....	0.084 "
Lime.....	0.39 "	Metallic Iron.....	51.26 "

Limonite—Lump sample from East River:

Comb. water.....	10.50	p. c.	Magnesia.....	0.21	p. c.
Silica.....	8.18	"	Manganese.....	1.25	"
Ferric Oxide.....	76.30	"	Phosphorus.....	0.02	"
Alumina.....	2.10	"	Sulphur.....	0.06	"
Lime.....	0.31	"	Metallic Iron.....	53.41	"

Fluxes.

Limestone, Springville, Pictou Co. Average analysis:

Moisture	0.20	p. c.	Magnesium Carbonate	4.90	p. c.	
Silica	3.10	"	Calcium Sulphate ...	0.20	"	
Alumina.....	0.24	"	Organic matter.....	—		
Ferric Oxide.....	1.86	"	Lime	} Available {	49.81	"
Calcium Carbonate..	88.94	"	Magnesia }		2.35	"

Pig Iron.

No. 1 Foundry.			Basic Iron.		
Silicon.....	2.85	p. c.	Silicon.....	0.40	p. c.
Manganese.....	0.54	"	Manganese.....	0.75	"
Phosphorus.....	0.90	"	Phosphorus.....	1.00	"
Sulphur.....	0.01	"	Sulphur.....	0.03	"
Gr. Carbon.....	3.70	"	Graphitic Carbon...	3.27	"
Comb Carbon.....	0.16	"	Combined Carbon ...	0.63	"
Copper.....	Nil.		Copper.....	Nil.	
Arsenic.....	"		Arsenic.....	"	
Barium.....	Trace.		Barium.....	Trace.	

Hematite Iron.

			No. 2 Foundry.		
Silicon.....	1.00	p. c.	Silicon.....	2.50	p. c.
Manganese.....	0.95	"	Manganese.....	0.55	"
Phosphorus.....	0.08	"	Phosphorus.....	0.90	"
Sulphur.....	0.08	"	Sulphur.....	0.012	"
Gr. Carbon.....	3.12	"	Gr. Carbon.....	3.20	"
Comb. Carbon.....	0.70	"	Comb Carbon.....	0.30	"
Copper.....	Nil.		Copper.....	Nil.	
Arsenic.....	"		Arsenic.....	"	
Barium.....	Trace.		Barium.....	Trace.	

No. 3 Foundry.

			No. 4 Foundry.		
Silicon.....	2.10	p. c.	Silicon.....	1.75	p. c.
Manganese.....	0.60	"	Manganese.....	0.65	"
Phosphorus.....	0.91	"	Phosphorus.....	0.92	"
Sulphur.....	0.02	"	Sulphur.....	0.03	"
Gr. Carbon.....	2.50	"	Gr. Carbon.....	2.00	"
Comb. Carbon.....	0.60	"	Comb. Carbon.....	0.90	"
Copper.....	Nil.		Copper.....	Nil.	
Arsenic.....	"		Arsenic.....	"	
Barium.....	Trace.		Barium.....	Trace.	

Fuels.

48 hour (Retort) Coke. Made in "Bernard's" Coke oven, from washed coal at Ferrona Iron Works.

Moisture.....	0.40 p. c.	Ash.....	7.22 p. c.
Vol. Comb. Matter...	1.60 "	Sulphur.....	1.15 "
Fixed Carbon (by		Phosphorus.....	0.01 "
diff.).....	90.78 "		

Slate, etc., from coal washer from coal used in making coke.

Moisture.....	1.00 p. c.	Ash.....	76.31 p. c.
Vol. Comb. Matter...	18.14 "	Sulphur.....	6.23 "
Fixed Carbon.....	4.55 "		

Washed coal used for making coke.

Moisture.....	1.07 p. c.	Ash.....	4.17 p. c.
Vol. Comb. Matter...	31.69 "	Sulphur.....	1.46 "
Fixed Carbon.....	63.14 "		

Culm Coal, one-third Springhill and two-thirds Reserve Coal, (C. B.)

Moisture.....	0.82 p. c.	Ash.....	11.06 p. c.
Vol Comb. Matter...	28.31 "	Sulphur.....	2.12 "
Fixed Carbon.....	59.87 "		

Another interesting exhibit is that of the Mineral Products Company, of Bridgeville, Pictou County. These people leased the Charcoal furnace at that place for the manufacture of ferro-manganese. The manganese was obtained from a deposit in New Brunswick. This deposit consisted of bog ore, which was dried and made into briquettes. It was smelted with the limonite ore of the East River, and made a product of good marketable value. The expense incurred in handling the manganese ore and its freight has been assigned as the cause of the abandonment of the enterprise. I regret to say that, owing to the absence of the manager from the Province, I am unable to give analyses of the raw materials and of the product.

In this district, in addition to the limonite ores, there are large deposits of specular, red hematite, spaltic and clay ironstone ores, which will no doubt before long be mined for the smelter.

In Cape Breton as yet there has been little iron ore development. An extensive and valuable deposit at Gillis Lake, is known as the Moseley mine.

The following set of analyses will tend to show its quality :

	1.	2.	3.	4.
Iron	63.45	63.20	58.90	64.10
Silica	6.96	6.42	13.38	4.71
Phosphorus ....	.0212	.014	.0257	nil.
Sulphur .....	.0631	.0604	.0041	.0027

The bed, which has been traced for several miles, averages about seven feet in thickness, and is associated with a crystalline limestone, presumably of laurentian age. It is within about four miles of deep water, and about eight miles from the Intercolonial Railway.

In the devonian strata in the neighborhood of St. Peter's, Richmond County, there are a number of deposits of specular ore, similar to those found in strata of the same age in Guysboro County.

The following analysis from the Micmac mine, about six miles from St. Peter's, will serve to show the class of this ore :

Iron	68.18	Sulphur .....	.15
Silica	2.48	Phosphorus .....	.05

Prospecting work at Whycocomagh, Cape Breton, has shown the presence of a number of beds of magnetite and red hematite up to twelve feet in thickness. Judging from surface indications, there is an extensive iron field in this locality. Analyses show metallic iron, from 49.13 to 63.20 ; Silica, up to 21.90 ; Sulphur, trace to .55 ; Phosphorus, trace to .49.

Very extensive deposits of a similar character occur at Nictaux, Annapolis Co., and are represented by a number of samples. A deposit of red hematite, at Torbrook, in this district, about six feet thick, was worked for some years, until the Londonderry Furnaces were closed. A description of the ores and analyses will be found in a paper on the Iron Ores of Nictaux read by me before this Institute a few years ago.

Other localities which have been drawn upon for samples are briefly as follows: Mira River, Cape Breton County, where there are several beds of red hematite from three to six feet thick.

Extensive deposits of magnetite and red hematite are reported from George's River, in the same county. As yet the explorations in these deposits have not been carried to any extent. The following analysis by F. A. Mason, of Halifax, will show that rich ore exists:

Metallic Iron.....	58.56	Phosphorus.....	.019
Manganese.....	1.98	Sulphur.....	.013
Silica.....	5.79	Titanium.....	.95

Londonderry, Colchester County, has for many years yielded limonite ore of very high quality. A very elaborate report and analyses were made some years ago by Dr. Selwyn, and published in the report of the Canadian Geological Survey. Samples of the varieties of limonite and specular ores, and of the carbonates, etc., worked here have been forwarded.

Quarries.

These notes refer to the Quarries in the northern part of Cumberland County, which furnished samples of their products.

Quarries at River John.—No. 1. This is the only quarry at present working in this district. It is situated at River John and about a quarter of a mile from I. C. Railway, and connected therewith by a good road.

It contains a reddish sandstone of fine grain, and has been opened for about 350 feet in length, exposing a face so far of about 14 feet. Stones are cut here up to about 33 cubic feet, though almost any size could be obtained with larger machinery. The seams are very regular in formation and lie nearly horizontal. Worked for nearly a year.

No. 2. Adjoins the first quarry, and resembles it in general characteristics, though the stone is of a lighter colour.

No. 3. About a quarter of a mile up the river from No. 1, was worked for six years intermittently. Many grindstones were cut in this quarry, which yields a firm grey sandstone.

Wallace Harbor.—The Wallace Grey Stone Co., Wallace Harbor, John Stevenson, Manager. This quarry is situated at Wallace, and a great part of the stone is shipped by water, though it is connected with the I. C. Railway by a good waggon road about two miles long.

Though the stone is carried to the wharf by horses, a tramway (gravity) could easily be operated, the quarry being situated on a hill. The distance is about a quarter of a mile. This quarry has been worked for a period of nearly thirty years off and on, and is still only partially developed. It produces an average of about 1,500 tons ("quarry") a year, of fine grained sandstone in two colours—"olive" and "bluish."

Blocks up to ten tons in weight and measuring fourteen feet are cut, and the greater part of the stone is shipped to the Boston and New York markets. The poorer stone is sold locally.

Wallace Harbor.—The G. P. Sherwood Co., T. C. Dobson, Manager. This quarry adjoins the quarry of the Wallace Grey Stone Co., and the same remarks apply to it also.

At Wallace Bridge the famous Battye Quarry is being operated by George Battye. Stone has been taken from this quarry since the year 1809, and there is still much in sight. It is situated on the I. C. Railway and the Wallace River. Chief market New York and Eastern States' cities. Blocks up to ten tons are cut. At present 25 feet of rock is shown in the face, with seams measuring from 2 to 6 feet in thickness. This is composed of a very uniform and beautiful sandstone, suitable for monumental as well as construction work.

On the River Philip, about five miles from Pugwash, is situated the quarry of McLeod & Embree. It produces a handsome red sandstone contained in seams from 2 to 7 feet, and shows altogether 20 feet in the face. Blocks cut to 8 tons. Has been operated for upwards of 30 years and usually ships to the

States. This year all the stone quarried is being supplied to Toronto.

The Atlantic Stone Co., Limited, R. S. Hibbard, Manager.—The quarry of this company is situated on Cumberland Basin, $3\frac{1}{2}$ miles from Joggins Station, on the Canada Coal Company's Railway, and 16 miles from I. C. Railway. The stone is shipped chiefly by water, in vessels up to about 300 tons. The market is mainly in the New England States, though the stones are sent much further west occasionally. 2,000 tons shipped per year. This quarry produces a very superior form of grindstone. Stones from half an inch to 14 inches thick, and up to 7 feet in diameter are cut, though almost any size that could be handled are procurable.

At Lime Rock, West River, Pictou Co., are sandstone quarries yielding good building stone. Samples are shown by Mr. J. H. Fraser. In the Merigomish district the strata lying above the productive measures yield grindstones and fair qualities of freestone.

The owners of quarries of granite, syenite, etc., neglected to respond to the invitation of the Department to send samples. The demand for granite is limited practically to the City of Halifax, where this stone is used to some extent for foundations, trimmings, and in the fortifications. The present available sources of supply are Shelburne, and the North-West Arm, near Halifax. At Nictaux there are blue varieties of granite of very fine quality, and in Cape Breton there are syenites, gneisses, etc., available for decorative and other purposes.

An interesting deposit of sandstones yielding building stone, grindstones, whetstone, etc., is found at Lower Cove, Joggins, Cumberland County. Samples of the raw and manufactured article are contributed by Mr. R. L. Hibbard. These quarries have been worked continuously for many years, and an extended market has been found for the grindstones. The quarry yields stones one-half to seven inches in thickness and up to seven feet in diameter. The superior quality of these

stones has secured a reputation for the district second only to that acquired by quarries more favorably situated in large industrial districts. Similar deposits are known at several places along the Joggins shore.

Marbles are represented by a sample from Escasoni, Cape Breton County, contributed by Mr E. T. Bown.

The following list shows the building stone quarries from which samples have been secured for the Exhibition:—A. Allen, W. W. Garmon, River John; T. C. Dobson, Wallace; McLeod & Embree, Pugwash; Wallace Graystone Company, Wallace; A. McPherson, Eight Mile Brook; R. L. Hibbard, Joggins; J. H. Fraser, Limebrook.

Barytes.

This mineral is known at Five Islands, Stewiacke, River John, and at Lake Ainslie, in Cape Breton. At present a few hundred tons are annually mined at the last-named locality. The ore occurs in a vein about nine feet wide, and is extracted through a tunnel. It is of excellent color and quality, and low in carbonate of lime. Samples of this mineral are exhibited by Messrs. Henderson & Potts.

Gypsum.

This mineral is found in great abundance in Nova Scotia. It is presented as hard and soft gypsum in every variety of texture and purity. The annual production is about 150,000 tons, principally from Hants County. Small amounts are quarried at other localities for local use, as an ingredient for fertilizers, etc. The exports from Hants County go to the United States, and a considerable shipment is made from Victoria County to Montreal and Philadelphia. Samples are exhibited from Windsor, Wentworth, St. Croix, Newport and other localities, in Hants County. Selenite is also shown from Enfield, in the same county, which has yielded a few hundred tons.

The Windsor Plaster Company also show the following products: (1) "Calcined plaster" used for putty coating, finishing, etc. (2) "Selenite cement" used for under coating, etc. (3) "Land plaster," ground gypsum, used for fertiliser manufacture, stables, etc.

Tripolite.

Of late years considerable attention has been paid to the infusorial earth deposits of the province, and to deposits of very fine grained quartz available for polishing, insulating, and other purposes.

Among the localities represented may be mentioned River Dennys, Inverness Co., where the Cairo Polishing Company are doing development work; Bass River, Colchester Co., where extensive works are carried on, the shipments for the last fiscal year amounting to 21 tons. The Bass River Infusorial Earth Company procure the raw material from Bass River Lake, where it is found in a bed about three feet thick, and purify it in a large plant, which has been in operation for over two years.

The Victoria Tripolite Company have commenced extensive operations near St. Ann's, in Victoria County, and are making a specialty of insulating material.

Molybdenite occurs at many points in the Province, but as yet deposits of workable size have not been reported. New Ross, Lunenburg, yields very large and fine crystals. A sample is shown from this district. A few tons have been shipped from Gabarus, Cape Breton County. From the Margaree district, Inverness County, are shown samples of ores of Tungsten, fuller reference to which will be found in these Transactions.

Antimony. The sulphide of this metal was some years ago worked intermittently at West Gore, Hants Co. The Messrs. McNeil, of Halifax, have lately given some attention to the district, and have proved three leads. The ore carries consider-

able gold values, and there appears to be some difficulty found in extracting it. Assays show the following values :

	I.	II.
Antimony.....	60.29 p. c.	43.73 p. c.
Gold.....	2.66 oz. per ton 2,000 lbs.	2.48 oz.
Silver.....	—————	.10 “

Fire clays occur at several places in the coal measures, and other horizons of the carboniferous, and are apparently valuable. The manufacture of fire brick was carried on for some time at Stellarton, but is, I believe, at present discontinued.

Allied economically to the fire clay is a sample of felsite from Coxheath, Cape Breton Co., which has been proven experimentally to make a good fire brick when mixed with about one per cent. of lime.

Samples of coal oil shale and their products of parafine, wax, illuminating and lubricating oil are shown from East Bay, Cape Breton Co., where a plant is being erected to treat them on a large scale. These shales occur in lower carboniferous conglomerates and sandstones near their junction with laurentian measures.

XI.—ON THE VARIATION OF THE RIGIDITY OF VULCANIZED INDIA-RUBBER, WITH TENSION.—BY THOMAS C. HEBB, B. A., *Dalhousie College, Halifax, N. S.*

(Communicated by Prof J. G. MacGregor on the 14th May, 1900.)

Mr. W. A. Macdonald* found in the course of experiments conducted in Dalhousie College last year, that the rigidity (kinetically determined) of a fresh or partially fatigued vulcanized india-rubber cord, when subjected to increasing tension, at first diminished, then reached a minimum, and finally increased; while in the case of a sufficiently fatigued cord, the minimum point seemed to disappear. But owing to a doubtful mode of gripping the ends of the cord, his experiments were not conclusive.

At Prof. MacGregor's suggestion, I have made the experiments described below with the object of settling this question and finding out what I could about the phenomenon.

For this purpose I have (1) used the method of gripping the cord which Mr. Macdonald employed in his last series of experiments in order to exclude the source of error affecting his earlier observations; (2) applied the static as well as the kinetic method of determining the rigidity; (3) made experiments both on the cord which Mr. Macdonald used and on fresh cords, and (4) adopted modes of procedure, suggested by the results of my earlier experiments, with respect to the time between the loading of the cord and the determination of the rigidity, and to the magnitude of the angle of torsion.

The cords used were cylindrical in section, about forty inches in length, and one-third of an inch in diameter. The grips consisted of pieces of brass tubing of the same diameter (inside) as the cord, in one end of each of which three longitudinal cuts had been made. The ends of the rubber cord were drawn into

* Proc. N. S. Inst. Sci., 10, 28, 1898-99.

the cut ends of these brass tubes and firmly fastened there by wire twisted around the tubes outside. Cords of considerable length were used, in order that the effect of the gripping at the ends might be inappreciable.

The cords were suspended from an iron bracket, moveable on vertical guide-posts which were attached to the wall of the laboratory, and capable of being firmly clamped to these posts at any desired elevation.

The upper brass tube passed through a wooden socket firmly fixed in the bracket. It was held in this socket by friction, and while it could be rotated by hand, there was no danger of its shifting its position otherwise. The brass tube projected above the socket, and carried a wooden disk, on which was a divided circle. A pointer fixed over the disk indicated the number of degrees through which the cord was twisted. Thus any desired torsion could be given to the cord at the upper end.

The brass tube at the lower end of the cord carried, in a plane perpendicular to it, a light wooden arm for the application of the twisting force in the static experiments, and which served as a platform for the stretching weights.

These weights were square leaden plates of about four inches' edge. They had holes of the size of the brass tube cut in the centres, and slits leading to them from the edge, so that they could be easily put on and taken off.

In applying the kinetic method, the cord was kept fixed at the top, while the lower end, with the plates attached, was twisted through some angle and then let go. The time of oscillation was then determined by means of a stop-watch. This datum, together with other data easily obtained, viz., length and diameter of cord, and moment of inertia of plates, gave the means of finding the rigidity. In determining the time of oscillation, it was soon noticed that it varied with the angle through which the cord was twisted. Hence the cord was always twisted through known angles. In the static, as in

the kinetic method, the rigidity varied with the angle, and here, also, definite angles of twist were always used.

In using the static method, the twisting force was applied at the end of the arm carried by the lower brass tube. In the earlier experiments it was applied by means of a thin silk string, horizontal and perpendicular to the arm, which passed over the pulley of a set of frictionless wheels taken from an Attwood's machine, and carried a small plummet of known weight. The plummet was so light that the cord was not appreciably deflected from the vertical. In order to make the friction as nearly as possible the same in all experiments with the same plummet, I observed the position of the end of the arm before the plummet was attached or the cord twisted, and then having attached the plummet, I determined the amount of twist to be applied in order that the arm might make small oscillations about this position.

Even with this procedure, however, successive observations showed a lack of agreement which was traceable to friction. Hence, in the later experiments, I used Mallock's* method of applying the force, which I found not only to give more consistent results, but to occupy less time. A small plummet of known weight which was suspended from the end of the arm by a fine silk string was drawn aside by a second silk string, which was kept horizontal, the two strings being in a plane perpendicular to the arm. The distance to which it was drawn aside was determined by the aid of a second plummet hanging freely from the end of the arm. The horizontal force at the end of the arm was then equal to the weight of the first plummet multiplied by the ratio of the distance to which it was drawn aside to the distance below the end of the arm of the point of junction of the two strings. These distances, together with the length of the arm, could be measured with considerable accuracy, and thus the torque to which the cord was subjected determined.

* Proc. R. S. L., 46, 233, 1889.

In most of the measurements made, the quantity under consideration was determined as a mean of several observations.

Lengths were measured by means of a beam compass reading to .01 inch. The limit of error of a mean value was found by comparing a number of such mean values with their mean, the greatest divergence being taken to be the possible error of a determination. It was found to be different according as it was the length of the cord or of a side of the Mallock triangle or of the arm, that was determined. In the two former cases the greatest divergence from the mean was .01 in., in the latter .005 in.

The diameters of the cords, which were approximately cylindrical, were found by means of a screw-gauge reading to .001 inch. The possible error was found by the above method to be .0005 in. Owing to the difference in diameter at different parts of the cord, it was found necessary to have marks on the cord, at which the measurements were always made.

The error that might be made in determining the angle of twist in the static method was estimated to be about a quarter of a degree.

The weight of the small plummet used in twisting the cord was found by means of a balance weighing to .001 gm. The method of weighing was that of substitution, and the limit of error was estimated to be .0005 gm.

The time of oscillation was found by means of a stop-watch divided into fifth-seconds, but capable of estimation to .1 sec. The limit of error was determined in the same way as in the case of length, and found to be about .04 sec.

In the static method the formula used for the calculation of the rigidity was the following: $n = 2 T l / \pi r^4 \theta$ in which T is the torque in lb.-inch units, applied at lower end of cord, l is length of cord in inches, r is radius of cord in inches, and θ is angle twisted through measured in radians. For the kinetic method the formula: $n = 8 \pi l I / t^2 r^4 g$ was used, in which l and r were

expressed as in the previous formula, I is moment of inertia expressed in lbs. and inches, and t is the time of a complete oscillation expressed in seconds. The moment of inertia of the plates used in stretching the cords was found by means of the following formula: $I = M(a^2 + b^2)/12$, in which M is mass of plates in lbs. and a and b are the lengths of sides of plates in inches. The moment of inertia of the brass tube at the end of the cord was found to be negligible.

The values of the rigidity determined as above would thus be expressed in inch-lb-second gravitational units.

The effects on the calculated values of the rigidity, of the above possible errors of the component observations, were calculated in a few cases, and were found in the static observations to be between 1.5% and 2.5%, and in the case of the kinetic observations to be between 2.5% and 3%.

My first observations were made on the cord which Mr. Macdonald had previously used. He had subjected it to repeated and prolonged extension, and found that the minimum point which in the earlier series of observations seemed to characterize the variation of its rigidity with tension finally disappeared. Since the time of his experiments it had lain for six months unstretched.

The static method was the only one employed, the torque being applied by means of the frictionless wheels. The procedure was as follows: First a weight was hung on the cord, and left there for at least a day. Then its rigidity was determined, after which the load was increased and the cord left for another day. On the third day the same process was repeated, and so on. It was not until later on in the experiments that the importance of allowing the loads to act for corresponding intervals of time was realized. The following table gives the results obtained:

TABLE I.

DATE.	Temp. (°C.)	Length. (inches)	Diam. (inches).	Angle of Torsion, (degrees.)	Torque (lb.-in.)	Rigidity.	Load (lbs)
Oct. 20..	.....	.....	.....	.....	.....	.....	1.611
“ 23 .	17.5	46.82	.322	917	.0209	58	“
“ 24 .	17.4	49.68	.313	1013	.0209	62	2.150
“ 26..	21.4	52.98	.303	625	.0117	69	2.678
“ 26..	20.5	53.07	.302	1093	.0209	71	“
“ 27..	19.5	56.96	.291	1235	.0209	78	3.216
“ 30..	18.5	57.28	.291	713	.0117	77	“
“ 30..	18.8	57.28	.291	1256	.0209	78	“
“ 31..	17.8	61.82	.278	1373	.0209	92	3.758
Nov. 1.	19.5	66.88	.270	1545	.0209	99	4.289

Although the above table shows considerable disagreement between successive observations, due probably in some measure to friction, to difference of temperature slightly, and to inequality in the times of application of the loads, the values obtained clearly increase with the tension, and give no indication of a minimum point. This result is in agreement with Mr. Macdonald's last series of observations, and seems to show that the rigidity increases steadily with tension in a cord which has been subjected to sufficiently prolonged extension, provided at least a day is allowed to intervene between increasing the tension and determining the rigidity.

The next observations were made on a fresh cord of a different rubber from Mr. Macdonald's. It was harder, and contained 60 per cent of pure rubber, according to the statement of the manufacturer. A freshly-cut surface showed a dark gray colour.

All the series of observations given below were made on rubber cords of this kind.

Both static and kinetic methods were applied, very little time being allowed to intervene between the two determinations, in order that the cord might be in the same state, as

TABLE II.

DATE.	Diam.	KINETIC OBSERVATIONS.						STATIC OBSERVATIONS.				KINETIC RIGIDITY.			STATIC RIGIDITY.		Load, (lbs.)	
		Length.	Temp.	Mo. of Inertia.	Time of Oscillation.			Length.	Temp.	Torque.		360°.	180°.	90°.	90°.	31°5.		
					360°.	180°.	90°.			90°.	31°5°.							
Jan. 11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.561
" 16	.397	35.06	18.2	1.44	3.65	3.42	3.13	35.06	17.9	.01536	.00574	159	181	217	141	150	"	"
" 17	.394	35.58	18.9	2.88	5.22	5.19	4.85	35.61	17.5	.01441	.00531	163	165	188	139	146	1.089	1.089
" 18	.389	36.23	14.7	4.42	6.60	6.37	6.23	36.24	15.5	.01444	.00555	167	179	183	148	163	1.644	1.644
" 19	.385	36.85	16.6	5.90	7.97	7.65	7.34	36.88	18.2	.01304	.00483	162	176	191	142	150	2.183	2.183
" 19	.381	37.54	17.9	7.37	9.16	8.96	8.76	37.57	19.8	.01201	.00433	163	170	178	139	143	2.711	2.711
" 20	.381	37.61	17.0	7.37	9.17	8.99	8.69	37.62	17.4	.01191	.00422	163	169	178	138	140	"	"
" 22	.380	37.64	18.4	7.37	9.34	9.18	9.03	37.69	18.4	.01226	.00449	159	165	169	144	150	"	"
" 22	.376	38.32	18.4	8.83	10.63	10.34	10.02	38.35	18.3	.01116	.00411	156	165	176	139	146	3.249	3.249
" 23	.376	38.43	18.3	8.83	10.47	9.93	9.41	38.46	18.3	.01120	.00397	161	180	199	140	142	"	"
" 24	.372	39.24	18.5	10.30	11.59	11.11	10.60	39.26	18.2	.01055	.00381	164	178	196	140	145	3.791	3.791
" 25	.366	40.18	15.0	11.74	12.67	12.41	11.93	40.18	15.5	.01026	.00368	170	177	192	149	153	4.322	4.322
" 26	.362	41.05	17.4	13.24	13.97	13.71	13.41	41.05	17.7	.00945	.....	169	175	183	147	.....	4.869	4.869
" 27	.356	42.11	14.8	14.75	15.10	14.76	14.53	42.14	14.5	.00891	.....	176	185	191	152	.....	5.422	5.422

nearly as possible, in both. In the static determinations of this, and of all subsequent series, Mallock's mode of applying the twisting force was used. The kinetic observations were made with different amplitudes of angle of oscillation, and the static observations with different angles of torsion. The general procedure was as in the former case. Table II contains the results.

In none of the columns of rigidity values of this table do the values found indicate any simple law of variation with tension. They do not even increase or decrease continuously as tension increases, but appear to oscillate between increment and decrement, and by amounts which are not accounted for merely by errors of observation. The variations cannot be accounted for even by errors of method, because in general both methods give similar variations. They may, perhaps, be partially at least, accounted for by defective procedure. Nevertheless, two conclusions may be drawn:—(1) The smaller the angle of torsion in the static determinations and the angle of oscillation in the kinetic determinations, the greater is the value of the rigidity obtained. Mallock drew the same conclusion as to kinetic rigidities from his observations. (2) The kinetic determinations show a point of minimum rigidity as tension increases; but the static determinations are not sufficiently exact to be decisive as to whether or not the existence of this point is independent of the method. Thus the kinetic observations bear out Mr. Macdonald's result that the kinetic rigidity exhibits the minimum point in the case of a cord previously unstretched.

The cord used in the last experiment being now in a state of tension, was experimented on in a reverse manner. It was left a day under the full load, when its rigidity was determined. Then one of the weights was taken off, and it was again left for a day under the diminished load, and its rigidity determined; and so on.

TABLE III.

DATE	Diam.	KINETIC OBSERVATIONS.						STATIC OBSERVATIONS.			KINETIC RIGIDITY.			STATIC RIGIDITY.	Load, (lbs.)
		Length.	Temp.	Mo. of Inertia.	Time of Oscillation.			Length.	Temp.	Torque.	360°.	180°.	90°.		
					360°.	180°.	90°.								
Jan. 27	.356	42.11	14.8	11.75	15.10	14.76	14.53	42.14	14.5	.00891	176	185	191	152	5.422
" 30	.357	42.20	18.5	14.75	15.20	14.91	14.63	42.21	18.5	.00845	172	179	186	142	"
" 31	.360	41.41	15.4	13.21	14.29	14.03	13.79	41.43	15.4	.00917	166	173	179	147	4.869
Feb. 1	.366	40.50	18.5	11.74	13.16	12.93	12.68	40.51	18.5	.00929	159	165	171	136	4.322
" 2	.370	39.69	19.0	10.30	12.09	11.92	11.51	39.71	19.0	.00941	155	169	171	129	3.791
" 3	.373	38.95	14.0	8.83	10.93	10.67	10.30	38.97	14.0	.00979	155	163	175	123	3.249
" 5	.377	38.20	13.0	7.37	9.80	9.35	8.90	38.20	13.0	.00998	151	165	183	122	2.711
" 6	.382	37.44	18.6	5.90	8.52	8.32	7.74	37.44	18.6	.01090	148	156	180	124	2.183
" 7	.385	36.76	19.0	4.42	7.10	6.82	6.33	36.76	19.0	.01166	153	165	191	127	1.644
" 8	.390	36.09	15.4	2.88	5.65	5.19	4.65	36.09	15.4	.01323	146	174	217	134	1.089
" 9	.395	35.34	17.0	1.44	3.90	3.57	3.16	35.34	17.0	.01418	143	172	218	134	.561

Table III gives the results of the observations. There is a greater uniformity in the way in which the values of the rigidity vary with change of tension than there was when the tension was increasing, which may be ascribed in part to the somewhat greater uniformity of the time intervals between changing the load and determining the rigidity, and in part to a greater permanence of internal structure produced by the previous prolonged extension. It will be noticed (1) that the values of the rigidity run through pretty much the same course as they did in Table II, when the tension was being increased, though the final values of Table III, in the case of the static rigidity for the greater angle of torsion and in the case of the kinetic rigidity for the greater angles of oscillation, are less than the initial values of Table II, and (2) that the minimum point is given not only by the kinetic results for the amplitudes 180° and 90° , but also by the static results, which shows that the occurrence of the minimum point is not due to a defect peculiar to the kinetic method.

To see what effect the time interval between the putting on of the load and the finding of the rigidity, had on the rigidity, a new cord was experimented with in the following manner:—A weight having been put on the cord, the rigidity was determined both immediately afterwards and after the lapse of certain intervals of time. Then another weight was added and the previous process repeated. Owing to lack of time, only the kinetic method was used. Table IV gives the results.

TABLE IV.

DATE.	Temp.	Diam.	Mo. of Inertia.	Length.	TIME OF OSCILLATION.			KINETIC RIGIDITY.			Load. (lbs.)
					90°.	180°.	360°.	90°.	180°.	360°.	
February 1....	19.0	.382	3.08	36.81	5.31	5.66	5.80	197	173	165	1.133
" 2....	19.0	.381	3.08	36.92	4.85	5.32	5.75	239	199	170	"
" 2....	19.5	.374	5.99	38.12	7.80	8.17	8.42	200	182	171	2.206
" 3....	14.0	.374	5.99	38.25	7.16	7.70	8.27	238	206	178	"
" 5....	13.0	.373	5.99	38.33	7.28	7.92	8.56	233	197	177	"
" 6....	18.6	.374	5.99	38.38	7.45	8.08	8.57	220	187	167	"
" 7....	19.0	.374	5.99	38.40	7.20	8.00	8.50	236	191	169	"
" 7....	19.0	.368	8.92	39.72	10.45	10.73	11.03	184	175	165	3.272
" 8....	16.7	.366	8.92	39.90	10.01	10.58	10.93	206	184	173	"
" 9....	17.0	.366	8.92	39.95	10.03	10.48	10.93	205	188	173	"
" 10....	14.4	.366	8.92	40.11	9.65	10.33	10.96	222	194	172	"

It appears from these results that increase of tension in a cord which has been under tension for some time immediately decreases the rigidity, but that if the cord is left under the tension the rigidity increases again. According to the longest series of observations made, the rigidity of a cord thus left under a constant load seems to pass through a maximum point, but that is perhaps doubtful.

Since the immediate effect of increase of tension is to decrease the rigidity, it might be expected that the twisting of the cord in the determination of its rigidity would increase the rigidity, and that consequently the greater the angle the cord is twisted through the smaller will be the value of the rigidity found. This expectation is borne out by the results as given in the tables. It was also noticed when taking several observations of the time of oscillation in order to get a mean value, that the first values were always the smallest, a fact which seems to indicate that the rigidity decreases with strain.

From the preceding it is easily seen that the procedure followed above was not such as could give a simple relation between the observed rigidity and the tension. For since the rigidity of a cord under tension varies with time, the experiments must always be made, if they are to give a definite result, when the rigidity is at a minimum or a maximum. Now the minimum value of the rigidity of a cord under tension appears from the last table to be immediately after the tension is applied. If, however, we decide to determine the rigidity when at its minimum, not only must the rigidity be found immediately after the tension is applied, but the rigidity of the cord due to its previous tension must not have had time to change from the minimum value. Hence the procedure should be as follows: Load the cord and find the rigidity immediately, then increase the load and find the rigidity immediately, and so on, the whole series of experiments being carried out in the shortest time possible.

With a new cord of the same kind as before, this procedure was followed, and the results of Table V obtained.

TABLE V.

DATE.	Temp.	Diam.	Length.	Mo. of Inertia.	TIME OF OSCILLATION.			TORQUE.	KINETIC RIGIDITY.			STATIC RIG.		Load, (lbs.)
					90°.	180°.	360°.		90°.	180°.	360°.	90°.		
Feb. 10	14.6	.372	34.58	1.44	4.25	4.41	4.50	.00851	150	139	135	100		.561
"	14.6	.368	35.39	2.88	6.18	6.32	6.47	.00827	151	144	139	103		1.089
"	14.4	.363	36.34	4.42	7.91	8.15	8.32	.00745	154	145	139	101		1.644
"	14.7	.357	37.45	5.90	9.52	9.75	10.03	.00715	156	149	140	107		2.183
"	15.0	.351	38.72	7.37	11.06	11.26	11.55	.00687	160	155	147	114		2.711
"	16.0	.345	49.03	8.83	12.53	12.78	13.18	.00636	166	159	150	117		3.249
"	16.7	.339	41.44	10.30	14.13	14.40	14.60	.....	169	162	158	.....		3.791

There is some lack of regularity in the results of this table so far as the determinations with smaller loads are concerned, but the divergence from regularity is probably within the limit of error of the observations. The results obtained with the larger loads exhibit much greater regularity than the results of the previous series of observations. The table shows that if the tension be increased as rapidly as is consistent with the determination of the rigidity at successive stages, the rigidity increases with the tension continuously, at first comparatively slowly, and finally with greater rapidity.

The comparatively slow increment of the rigidity under the smaller loads would suggest the possibility that the rigidity may not appreciably vary with the tension at all under the circumstances aimed at in the experiments. For in the light of the results of Table IV the larger values of the rigidity under the greater loads may be due entirely to the time effect of the previous increments of load.

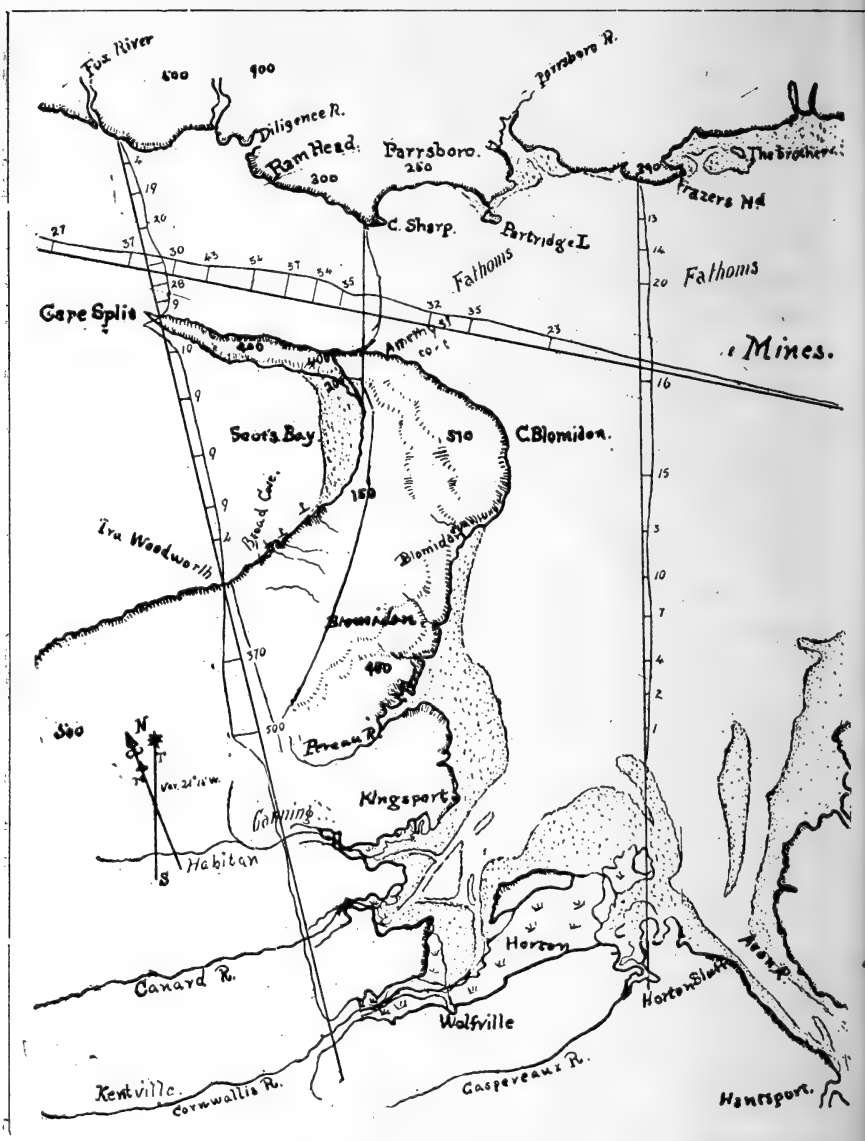
XII.—RECORDS OF POST-TRIASSIC CHANGES IN KINGS COUNTY,
N. S.—BY PROF. E. HAYCOCK, *Acadia College, Wolfville,*
N. S.

(Read 9th April, 1900.)

It was my privilege last Autumn to make a hasty survey of that part of Kings County lying north of Canning, including Cape Blomidon. Several interesting problems were suggested during this trip, which I hope to follow up in the future.

I had in view two definite aims in visiting this region. The first was to look for the contact of the basaltic trap of the North Mountain with the underlying north-westerly dipping sandstone, and I hoped to find this contact laid bare and accessible to observation in the natural cross section formed by the line of cliffs which extends westwardly from Cape Blomidon to Cape Split. This line of cliffs was carefully examined from Amethyst Cove, where the trap extends beneath the sea, eastward to Cape Blomidon where red sandstone cut into many fantastic shapes by wind and water rises nearly two hundred feet and is surmounted by a sheet of black basaltic trap some two hundred feet in thickness ending abruptly in vertical cliffs behind and above the towers and bastions of the sandstone. Although the place where the contact of the two formations reaches the beach is easily determinable, and is marked by a long sloping line of springs, the talus of loose blocks and debris from the trap above is so great that at no point was the actual contact visible or accessible, so that the problem to be settled, whether the trap was poured out on a smooth sea bottom or on an old eroded land surface, remained undetermined.

The second object of the trip was to examine the coast section south-west from Scot's Bay. In the Transactions of the Institute for 1893-94, (Volume VIII., pp. 416, 419,) Mr. R. W. Ells mentions the occurrence, in this vicinity, of a calcareous



NORTH-EAST PART OF KINGS COUNTY, N. S.

Scale: About four miles to one inch. Vertical scale 2400 feet to one inch. Depth of water in fathoms.—For Mines, read: Basin of Mines.

sedimentary formation overlying the trap of the North Mountain which was hurriedly observed by him in 1876. He states that no fossils had been found in these rocks, but concludes from the superposition of this formation on the trap that it is of more recent date. He does not hint at its probable age further than the above, but remarks that Prof. Bailey has reported rocks of somewhat similar nature in association with the trap of Digby Neck. Having been unable to find the statement in any of Prof. Bailey's writings accessible to me I made inquiry of him and found that he did not know of such a formation, or of having made the statement ascribed to him. This being the state of knowledge in regard to these rocks I hoped to find something that would throw light upon their age and possibly reveal a part of the geological history of this region during that long period so blank in records in Eastern Canada and New England, from early Mesozoic to the Glacial period.

In pursuit of this purpose I examined the shore south-west from Scot's Bay and was pleased to find for about four miles occasional good exposures in the coves of the formation mentioned by Dr. Ells, until Ira Woodworth Bay was reached. This is the exposure mentioned by him and was the most westerly outcrop seen. Beyond this according to local authority none of the rocks mentioned are found. Considerable value can be ascribed to the local accounts in this case owing to the search for amethysts which occur in cavities of masses of red jasper in some of the layers of limestone, and are collected by the inhabitants to supply the tourist trade. Only a hurried survey was made on this occasion and but one fossil was found, which, tho' poorly preserved, was plainly the coiled shell of a gastropod. The general appearance of the strata, however, led me to hope that better results would repay a careful and systematic search.

On November 6th, I left Wolville for a further study of this interesting formation. The results of my observations on this trip I will endeavor to put before you.

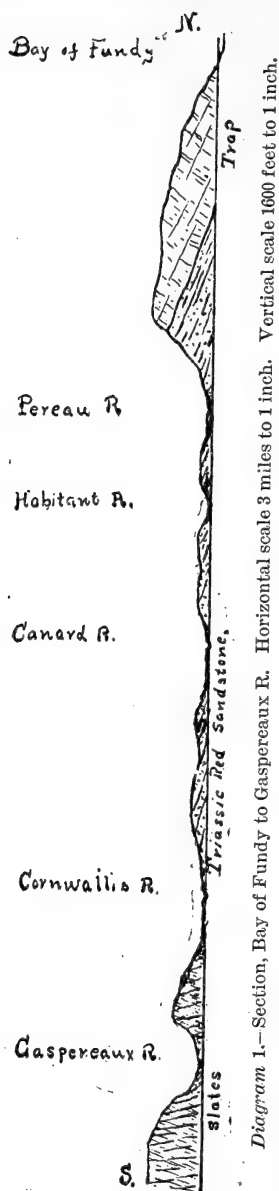


Diagram 1.—Section, Bay of Fundy to Gasperaux R. Horizontal scale 3 miles to 1 inch. Vertical scale 1600 feet to 1 inch.

The general topography of the region alluded to is probably familiar to you all, as well as the common explanation of the geological structure, which appears to be, in the main, correct. From the parallel east-north-east and west-south-west ridges of slate and sandstone of later Palæozoic age, which extend along the south-east side of the Cornwallis Valley, a slightly undulating rich farming country stretches away to the north-west for some ten miles to the abrupt escarpment bounding the valley on its opposite side. The principal topographic features of this beautiful valley are three low ridges parallel in general trend with the older hills before mentioned and separated from each other and from the bounding ridges by long tongues of fertile dyked marsh in the basins of the Cornwallis, Canard, Habitant, and Pereau rivers. The existence of these ridges seems to be due to the occurrence of coarser harder groups of strata in the underlying red sandstone which dips with considerable uniformity and regularity to the north-west at angles of from eight to ten degrees. The ridges correspond with the strike of the formation and the valley topography is apparently one of erosion. The wearing out of the valleys took place when the country stood at a higher level, and the marsh deposits of

recent times now extend for several miles up the drowned valleys. That this topography is probably Pre-glacial is indicated by the occurrence of a layer of Boulder clay of variable thickness mantling both hill and valley. The changes in topography since the disappearance of the ice of the Glacial period are exceedingly slight in this region and are confined almost wholly to the deposition, during a subsequent slight submergence, of some banks of stratified sand and gravel, some wearing away and retreat of the coast cliffs, and the filling-in of the river basins mentioned.

The North Mountain has the prevailing trend of the other ridges, and would appear to owe its present elevation above the valley to the harder and more resistant character of the sheet of volcanic rock, which protects the underlying soft sandstone from the action of the eroding agents that have worked with such effect upon the unprotected sandstone to the south-east. The junction of the sandstone and trap is some two hundred feet or more above the floor of the valley, and the conviction is forced upon the observer, when looking south-eastward from this point that not only the smaller valleys mentioned but also the whole broad depression he has crossed has been worn out of the soft red sandstone, and that excepting minor inequalities of surface the present relief of this part of the Province is wholly due to differential resistance of the underlying rocks.

The trap sheet retreats more rapidly along its edges than the sandstone owing to frostwork and its vertical jointing, and when they both appear in the face of the escarpment the overlying trap is never overhanging but always well behind the sandstone which generally forms a steep slope upon which the fragments of the trap are precipitated, forming broken masses which conceal the contact of the two formations. Because of the soft nature of the sandstone and its calcareous cement it weathers much more rapidly than the trap wherever exposed to the action of rain and wind, but since the jointing is not well developed it is not affected to a very great extent by the action of the frost.

From the top of the divide, which is near the edge of the escarpment, the surface slopes away to the north-west at angles of from eight to ten degrees. This is about the inclination of the beds of trap rock, and the present surface therefore corresponds in general inclination with the original surface of the formation. This ridge is cut by transverse valleys, the bottoms occupied by small brooks which seem altogether too small to have excavated the trenches they now occupy. A bank of boulder clay containing glaciated pebbles was seen resting in the bottom of a ravine on the floor of trap rock over which one of the larger brooks is now flowing. If these depressions were filled with the boulder clay of the Glacial period, the work since that time has been wholly expended in clearing out their ancient channels and the brooks have but just begun to renew their excavation on the Trap rock.

The four miles of coast examined form the south-east shore of Scot's Bay, and from Ira Woodworth Bay, Cape Split, the terminating point of the huge wall of rock forming the opposite side of Scot's Bay, bears nearly north. At this point the shore swings from south-west to about west-south-west which is the general trend of the coast for some sixty or seventy miles. With the exception of the Amygdaloidal character of the Trap, the shore below high water mark is not unlike many other portions of this Bay of Fundy coast. Beachy coves are more common because of the relatively sheltered position, but between these the black rough rocks slope seaward in sheets and reefs with very few outlying rocks and ledges. The sea at high tide washes the bases of a line of low cliffs some twenty to forty feet high, except in the deeper coves, where a narrow strip of gravel beach is left uncovered by all but the highest tides. Several brooks empty in small coves within the area examined and in their beds the extent of the shore formations landward can be traced.

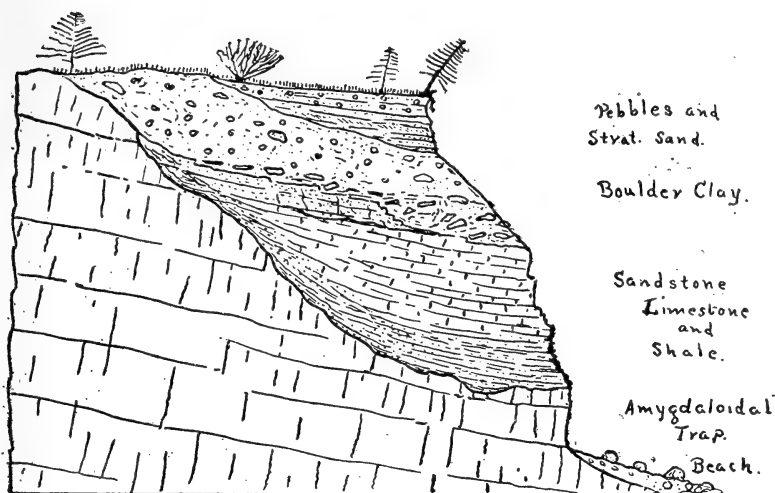


Diagram 2.—Section in Ira Woodworth Bay.

In the shore cliffs four distinct formations are revealed and in the ascending order they occur as follows:—

1. Trap Rock.
2. Sandstone and Impure limestone, 20-30 feet.
3. Boulder clay with striated stones in irregular masses, 20-30 feet.
4. Stratified sand and gravel 4 to 6 feet in thickness about thirty feet above high water mark.

Trap Rock.

The Basaltic Trap is, in this locality mainly amygdaloidal and occurs in sheets varying from two or three to many feet in thickness. The strike corresponds to the general trend of the shore. In many places the beds are intersected by a network of shrinkage cracks which have been subsequently filled with a dark reddish brown jasper. This is more resistant than the trap and the veins form a network of intersecting ridges separating saucer shaped depressions a foot or more in diameter. As the Trap approaches its contact with the limestone it becomes

more and more decayed until at the contact the rock is so loose and unconsolidated that it will scarcely hold together to form a hand specimen.

Sandstone and Impure Limestone.

The lower layers of the calcareous formation are largely made up of this disintegrated material but it is not found more than two or three feet from the contact. These lower layers are poorly defined and conform to the minor inequalities of the eroded surface of the Trap. The Trap debris then gives place to a fine grained light grey to green sandstone with calcareous cement, in thin laminae, which is overlain by beds of impure limestone from one to three feet thick alternating with thinner layers containing flint-like quartz bands. At one spot in Broad Cove a brown sandstone in beds three or four feet in thickness is seen overlying the limestone. The maximum thickness of this sedimentary formation would be about twenty-five feet. Altho several brooks cut across these beds at right angles, in only one can the limestone be traced, and there for a distance of but twenty or thirty yards from the beach where the trap appears in the bed. The other brooks have cut completely through and flow over the underlying trap until the beach is reached. This shows how little remains of what must have been an extensive formation and explains in part why it remained so long unnoticed.

The dip of these beds is, at first, somewhat confusing. On the north-east sides of the coves it is always to the south-west, and at angles as high as twenty degrees. On the south-west sides of the coves it is correspondingly high to the north-east. In the bed of the brook mentioned, which is in the centre of one of the coves, the dip proved to be from three to five degrees to the north-west. At several places the trap was visible beneath the apparent synclines and showed no corresponding deformation. Moreover, the variable inclination of the layers was there seen to be that of the contact surface of the trap on which they rest. As the layers recede from this surface they become more uniform in inclination which is seen to be to the north-west at an angle



FIG. 1.

BROAD COVE, LOOKING EAST, SHOWING LIMESTONE AND SHALE RESTING ON AMYGDALOIDAL TRAP.



FIG. 2. — UNCONFORMABLE CONTACT OF GREENISH SHALE WITH AMYGDALOIDAL TRAP IN BROAD COVE.

To face page 294.

slightly smaller than that of the trap, or the same as the observation taken in the brook.

In some of the lower fine grained calcareous shales sun cracks frequently occur and together with trail-like markings and carbonaceous impressions of branching fucoid-like plants point to shallow water or tidal conditions prevailing during the deposition of the lowest layers. The fineness of the material of these lowest layers also indicates a very gradual quiet submergence of the disintegrated Trap rock and the absence of heavy waves upon the subsiding beaches. The heavier bedded limestone is quite free from inorganic sediment, and is a deposit in deeper and purer water. The heavy bedded brown sandstone marks some change bringing about a great increase of inorganic sediment. Whether it was a re-elevation bringing the area nearer shore, or advent of currents carrying such sediment is at present undetermined.

Fossils occur in the underlying shale and limestone, altho' they are, as a rule, poorly preserved. Among those collected are fish scales and teeth, objects resembling the seed cones of gymnosperms, marine fucoids, and long, tapering, generally straight, objects that are thought to be the shells of cephalopods. These occur in the limestone and calcareous sandstone often in great profusion and may reach a length of eight or ten feet, and a diameter at the larger end of eight or nine inches. The smaller ends are rounded, and usually about one, though sometimes two or three, inches in diameter. They are cylindrically or longitudinally knobbed, hollow in the centre, and composed mainly of a red jasper. That these forms are of organic origin and are not concretions is indicated by their similarity in form and by their lying, in one bed, in such numbers that they cross each other in every conceivable way, but always the characteristic form of each individual can be determined. In all cases the finer laminæ of the beds are pressed down beneath by the weight of the object, and those deposited after curve up over it without interruption. Other forms occur here also. One of these was twenty-seven inches in diameter and appeared cup-like in shape.

It has been stated that these strata rest unconformably on a surface of decomposed trap, and that the lower layers are made up, in part, of the triturated fragments of the trap. This would indicate that after the pouring out of these lava sheets their surface was above water, was carved into valleys and hills, by the streams of the time, and subjected to the decomposing action of atmospheric agencies and vegetation, until the ancient surface came to present the irregular and weathered aspect that we may now see on portions that have been subjected to similar action during recent geological time. This necessarily long exposure preceded the subsidence and submergence during which the stratified formation was deposited and would indicate, to my mind, that at least a whole geological period had intervened between the outpouring of the trap and the deposition of the marine formation unconformably upon its weathered surface. The trap is considered to be of Triassic age and I would place that of the limestone as probably Cretaceous. Again, from Cape Cod southwards marine deposits were laid down along the Atlantic border during Cretaceous times. Altho' I have as yet been unable to find any traces of foraminifera in the soft greenish sandstone that occurs in one of the coves, yet the general aspect of the fossils so far found is also suggestive of Cretaceous age.

The hollows or depressions in which these remnants are preserved are at present small valleys, occupied by brooks and terminating on the shore in small coves which also owe their existence to the erosion preceding the deposition of this formation. The Topography of this portion of the North Mountain is thus shown to be much older than the Glacial period and not only are the brooks flowing in Mesozoic channels but the Bay of Fundy waves are again washing the shores of coves from which they have been excluded since the Mesozoic period.

The facts observed here are in accord with the conclusion arrived at from a comparison of the present stream beds with the streams that now occupy them. Some of the gorges in this area are equal in magnitude to those of the secondary streams of the South Mountain, although the volume of water now flow-

ing in them is insignificant. The cross trenches in this particular locality are, however, small as compared with those that cross the mountain at intervals of a few miles throughout its length, some of which are scarcely above sea level, others as Digby Gut and Petite Passage 150 to 200 feet below.

These deep gorges are probably Pre-glacial, as well, since they are partly filled with boulder clay and usually, if not always, set opposite to corresponding depressions in the older hills on the opposite side of the valley. The ice of the Glacial epoch flowed over ridge and through hollow alike, and beyond sweeping away the decayed and shattered layer down to the undecomposed rock seems to have had little effect in transforming the general topography of the country. These gorges then are doubtless Pre-glacial, but how much older? Though much larger they are of the same character as the smaller hollows filled with the sedimentary limestone, and are probably of the same, or Mesozoic age. Although direct evidence of this has not yet been obtained it may exist, only awaiting the coming of a careful observer.

The most significant features of these greater gorges is their positions, just mentioned, nearly opposite to corresponding river gorges on the south-east side of the valley. Almost every deep gorge in the North Mountain has its corresponding river valley in the higher ground of the South Mountain opposite. The depressions reaching the Bay of Fundy coast at Parker's Cove, Digby Gut, Sandy Cove, opposite the Lequille, Bear, and Weymouth rivers are striking examples. A possible if not the only plausible explanation of this fact, taken in connection with the evidence of the great age of these depressions, is that they are respectively the old outlets of Mesozoic rivers that flowed north-westwardly across the sandstone and its overlying trap sheet, draining a country more extensive than the present Nova Scotia, because of its greater elevation, and with their greater volume wearing broad channels through the red sandstone but abrupt and precipitous trenches in the trap. The effect would be the same in the basins of the smaller streams such as those now

heading back to a low divide some three or four miles from the coast.

During the submergence of the region in late Mesozoic or early Tertiary times, the streams were drowned by the sea and the silicious and calcareous deposits described were laid down in the old river valleys. Deposits forming in this way would be protected from the disturbances of the open shore, and probably be composed of fine sediment laid bare at each low tide and dried and sun cracked in bright warm days until carried below the tidal limits by the slow subsidence of the whole region. The limestone deposits indicate a submergence great enough to have formed large inland basins in the broad valleys in the sandstone country south-east of the edge of the trap sheet. These were possibly separated from each other by low divides which would be gradually lessened by the rapid vertical decay of this rock referred to earlier in this paper. When once covered by the sea, the swiftly moving north-east and south-west tidal currents characteristic of this region would scour out the valley at a rapid rate, while the trap sheet would not retreat along its edges at a corresponding rate since the frost work had not yet been inaugurated, mild and warm climates extending at this time even within the Arctic Circle. On the re-elevation of the country in middle or late Tertiary times, the rivers would not return to their ancient channels across the trap which were now higher than the valley floor and filled in with deposits of the kind described, but would flow along the valley parallel with the mountain in either direction only discharging at the lowest outlets as Digby Gut at the south-west and Minas Basin and Channel at the north-east.

The colder climates of late Tertiary times were now setting in with winter frosts and snow, and the sheet of trap would begin the rapid horizontal retreat which has continued until the present day.

Boulder Clay.

Boulder clay containing many striated stones from local sources occurs throughout this whole region and is seldom absent

except from the loftier and more exposed portions of the ridges. The prevalence of compact and amygdaloidal trap from the North Mountain in the Boulder clay all over the south side of the valley, as well as the rounded and worn north facing slopes of the elevations indicate that the general movement of the transporting agent was from the north. The general trend of all the striations I have yet seen in this vicinity is in the same direction.

Although Boulder clay is rarely seen along the exposed side of the North Mountain except when sheltered by the precipitous walls of the deep gorges which have been alluded to, on the stretch of shore south-east of Scot's Bay, deposits of considerable thickness rest alike on trap and limestone and contain striated fragments of both formations. In general the mass has the same decided red color as the sandstone cliffs underlying the trap at Cape Blomidon. One exception to this occurs in Ira Woodworth Bay where the underlying portion of this deposit is completely made up of a calcareous light grey clay mixed with angular, occasionally striated fragments of the sedimentary formation. It is wholly composed of the broken and pulverized layers of this sedimentary formation and passes up abruptly into the red clay and trap boulders among which no trace of limestone could be found.

The abundance of boulder clay on this strip of coast proves it to have been a region of deposit rather than of erosion during its burial beneath the ice of the Glacial Period. That deposition was not continuous is shown, however, by the occurrence of the debris of the adjacent calcareous strata at the most westerly point at which these strata were seen. Farther east the red deposits seemed to rest directly upon the light grey limestone and sandstone and these portions do not seem to have suffered as much from the grinding action of the ice sheet.

The evidence from striations and from travelled boulders prove that the general movement of this ice sheet was from the north. From Ira Woodworth Bay, Cape Split bears due north and from this bold Cape a line of vertical cliffs from two to four hundred feet in height extends eastward for eight miles to Cape

Blomidon, offering a huge barrier to the advancing ice sheet which would deflect the main current, and leave a sheltered area behind where the eroding action would be small or absent altogether, and the conditions favorable for deposition during the decline and disappearance of the ice.

This protected area would extend about to Ira Woodworth Bay, whence westwardly the shore would be exposed to the full sweep of the mass passing to the westward of Cape Split. It is significant that east of this Bay occur the heavy deposits of boulder clay while to the west a bold bare coast of black forbidding trap extends for a hundred and twenty miles with but an occasional heap of red boulder clay that has been deposited behind some projecting cliff. Have we not here a simple explanation of the preservation of this fragment of marine limestone, this mere remnant of what must have been a formation of considerable extent, the sole representative in north-eastern America, containing the only known records for that region, of the Geological history of the long period of time between the Triassic and the Glacial periods.

Stratified Sand and Gravel.

But the records preserved in this strip of coast do not end with those of the Glacial period. Overlying the boulder clay is a deposit of stratified sand and gravel several feet in thickness, the base of which is now some thirty feet above high tide level. The upper limit of this formation was not determined, but the coarse and water worn character of the material classes it as a shore deposit, laid down within or but slightly below tidal limits. This formation has been noticed at Wolfville, Pereau and at several localities in Digby County. In the Cornwallis Valley it consists mainly of stratified sands in which the cross bedding indicates that during their deposition the currents flowed strongly both to the north-east and to the south-west, or parallel with the general trend of the valley.

These deposits tell of a submergence succeeding the Glacial period of at least thirty or forty feet and a re-elevation of at

least the same magnitude. It is probable that during the deposition of these beds the waters of Minas Basin, Digby Basin and St. Mary's Bay were connected and that the present flat and fertile valley stretching from the base of the North Mountain to the low Palæozoic hills on the south was a shallow strait through which twice a day the ebb and flood swept swiftly planing down the valley to a uniform level but sweeping up here and there long bars of shifting sands. These still remain but form minor features in the topography of the valley.

This shallow strait was sheltered from the rougher waters of the Bay of Fundy by the protecting barrier of the North Mountain and the deposits in the valley are much finer than those of the same age on the Bay of Fundy coast. The North Mountain itself was cut up into a line of narrow islands by the submergence which brought the bottoms of several of the deeper gorges below sea level, and the old shore lines in some of these may still be seen. The length of the chain was practically the same as at present since Briar Island the westernmost extension of the trap ridge then formed two small islands rising some fifty feet above the sea as shown by the old shore line about eighty feet above the present sea level.

When the land again arose, the waters left the valley, the rivers extended seaward removing the sand and gravel from their old channels, wearing them deeper, and the now submerged forests grew.

But again a gradual subsidence followed. The sea slowly advanced up the river channels. The fine sediment brought down by the rivers was arrested by the tidal currents and deposited in their shallow estuaries, and the marine marshes were formed.

This is as we find it at the present day. The changes are still in progress. The history of this region which we have followed from early Mesozoic times to the present, or as much of it as the records known to us reveal, is still being written in the changing surface features of the land, the retreating coast line, and the strata now forming off our shores. Every change,

no matter how small is thus recorded, and this account is merely an attempt to read aright such records as have come under the observation of the writer in a few hasty journeys among the newer formations of our Province.

Brief and limited as these opportunities for observation have been, they have convinced me that the field for Geological investigation, in this region at least, is ample; that it is wonderfully rich in undiscovered facts; and that for variety in lithological, in palaeontological and in structural features, it is unequalled by any area of similar extent in eastern North America. That such is the case is shown by the results achieved by Sir J. Wm. Dawson during the third quarter of the century and set forth by him so clearly and interestingly in his "Acadian Geology," a work which must ever remain for us a model of close observation, broad and scientific induction, and elegant expression.

Because of its exceptional richness, however, the field has not yet been exhausted, in the region of Minas Basin and westward the soil has merely been broken. The broader relations of the great formations to one another have been worked out and their relative age established, but in knowledge of their lithological composition, fossil contents, structural peculiarities, conditions of deposition, relation to present topographic features, etc., we are almost wholly deficient. The field is alluring and full of promise to the Geologist. Let us who are native born reap the rich harvest of facts before we are anticipated by workers from the over-crowded fields of New England.

XIII.—PHENOLOGICAL OBSERVATIONS, CANADA, 1899, BY A. H. MACKAY, LL. D.

(Read 9th April, 1900.)

The schedule on which the observations referred to here were recorded specifies 100 different objects, some with subdivisions. Of the great majority of them, two classes of observations are asked to be recorded: "When first seen," and "When becoming common." In the tabulated dates recorded by the Botanical Club of Canada, given at the end of this paper, the first series only is taken. The character of the schedule is also indicated in these tables of observations at the thirteen stations throughout Canada.

The identical schedule is also used in the public schools of the Province of Nova Scotia. The observations here are made by the pupils in attendance as a part of their "nature study," when going to and returning from school, and are tested and recorded by the teacher in duplicate, one copy of which is preserved as a local record, and the other is sent with the school returns to the Inspector for the Education Office.

Seven hundred and twenty-five school sections (school districts, localities, or stations) returned schedules of observations, the majority more full than those of the thirteen stations of the Botanical Club reporting. The summation of these in tabular form would require a large volume, and cannot, therefore, be attempted here. The schedules are bound up in a volume for each year, so that the information may not only be preserved for the future use of students, but may be conveniently accessible. The series of volumes will be a mine of information bearing on at least one phase of the problem of secular variation of climate.

The same ten plants taken last year are here selected from the list of one hundred objects for the purpose of comparison

as to the average time of *first* flowering and when flowering was *beginning* to become common. In some counties the observations were so full that thirty good stations could be selected for averaging, ten from the *sea coast*, ten from *low inland* settlements, and ten from *high land* settlements. These average dates or phenochrons of flowering are arranged in parallel columns for the sake of comparison. In some counties only twenty satisfactory stations for averaging, and in others only ten, were found, as can be seen at a glance from the tabulation of the figures.

The average phenochron for each plant's *first* flowering and flowering *becoming common* is calculated for each county, and the mean of the two series is finally taken for comparison with the similar general phenochron for the same phenomenon in 1898. These general phenochrons are plotted on the accompanying diagram so as to show their curves through the counties of the Province arranged in a linear series beginning at the west and south, and proceeding to the east and north.

This order of the counties will be uniformly followed in future plottings of the phenochronic curves, for the greater ease of comparing those of one year with those of another. Last year the counties were arranged in the order of their most general phenochrons. Were the same rule followed this year the positions of some of the counties would be changed; but if the positions of the counties remain fixed the configurations of the phenochronic curves will illustrate the variations very clearly from year to year.

On a future occasion I propose to plot the phenochrons of the same phenomena running through the counties of the province for two or three consecutive years, in order to study the character of the annual observations, or the peculiarities of climate or flowering. Unfortunately, we cannot be sure of the degree of variation originating in the latter causes until we are sure of a uniform system of correct observations symmetrically distributed.

Apart from any generalization of value which may be expected from such work carried on continuously for years, it is found to be a valuable stimulus to the formation of habits of accurate observation in the pupils of the public schools, and to the study of nature on the road to and from school, when it does not interfere with any other study, and when it adds interest and often amusement to otherwise monotonous road travel. For this purpose alone the trifling cost of supplying the schedules are many thousands of times repaid.

The names of the *ten* plants whose average dates of flowering are given in the columns following, as described, cannot be given on the same page with their phenochrons without overcrowding. The names are, therefore, to be understood to be prefixed in the following order to each column :

1. The Mayflower (*Epigœa repens*).
2. The Blue Violet (*Viola cucullata*).
3. The Red Maple (*Acer rubrum*).
4. The Dandelion (*Taraxacum officinale*).
4. The Strawberry (*Fragaria Virginiana*).
6. The Wild Red Cherry (*Prunus Pennsylvanicum*).
7. The Tall Buttercup (*Ranunculus acris*).
8. The Indian Pear (*Amelanchier Canadensis*).
9. The Cultivated Apple (*Pyrus malus*).
10. The Lilac (*Syringa vulgaris*).

FLOWERING PHENOCHRONS

*Of the foregoing ten Plants in the Eighteen Counties of Nova Scotia,
for the year 1899.*

YARMOUTH COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inlands	High-lands.	Average.	Coast.	Low Inlands.	High-lands.	Average.	Annual date.	Mensual date.
98.2	87.8	.....	93.0	109.7	103.7	.....	106.7	99.85	10 April.
117.8	118.2	.....	118.0	127.4	124.2	.....	125.8	121.90	2 May.
125.2	129.2	.....	127.2	130.5	134.2	.....	132.3	129.77	10 "
117.4	119.7	.....	118.5	129.6	127.5	.....	128.5	123.55	4 "
118.3	115.6	.....	116.9	131.8	125.8	.....	128.8	122.87	3 "
135.9	137.3	.....	136.6	144.1	142.9	.....	143.5	140.05	21 "
141.8	130.6	.....	136.2	153.8	141.2	.....	147.5	141.85	22 "
142.8	136.6	.....	139.7	146.6	143.4	.....	145.0	142.35	23 "
147.5	139.0	.....	143.2	157.4	148.9	.....	153.1	148.20	29 "
160.4	151.6	.....	156.0	166.9	158.0	.....	162.4	159.22	9 June.
130.53	126.56	.....	128.54	139.78	134.98	.....	137.38	132.96	13 May.

SHELBURNE COUNTY, 1899.

99.9	101.2	.....	100.5	108.2	110.9	.....	109.5	105.05	16 April.
122.0	121.0	.....	121.5	129.5	127.0	.....	128.2	124.87	5 May.
125.5	124.0	.....	124.7	134.2	133.9	.....	134.0	129.40	10 "
120.0	123.5	.....	121.7	132.7	131.1	.....	131.9	126.82	7 "
121.8	121.9	.....	121.8	133.2	130.1	.....	131.6	126.75	7 "
142.0	140.5	.....	141.2	150.0	146.8	.....	148.4	144.82	25 "
135.7	144.8	.....	140.2	148.4	151.0	.....	149.7	144.97	25 "
138.1	137.6	.....	137.8	146.7	146.6	.....	146.6	142.25	23 "
147.0	147.0	.....	147.0	155.1	155.4	.....	155.2	151.12	31 "
156.7	157.8	.....	157.2	163.9	163.3	.....	163.6	160.42	10 June.
130.87	131.93	.....	131.40	140.19	139.61	.....	139.90	135.65	16 May.

DIGBY COUNTY, 1899.

*	*			*	*				
102.4	102.6	104.1	103.0	110.6	117.4	122.0	116.6	109.86	20 April.
119.7	120.2	122.6	120.8	127.2	130.6	127.3	128.3	124.58	5 May.
130.4	133.4	126.2	130.	137.8	138.8	132.0	136.2	133.10	14 "
118.4	121.4	123.9	121.2	128.0	127.8	121.3	125.7	123.46	4 "
116.4	120.2	119.7	118.7	128.8	130.4	128.2	129.1	123.95	4 "
136.8	143.6	136.9	139.1	148.2	153.8	143.6	148.5	143.81	24 "
145.8	146.4	143.6	145.2	153.2	156.4	150.7	153.4	149.35	30 "
141.0	136.8	132.5	136.7	149.6	148.2	138.2	145.3	141.05	22 "
144.8	142.4	140.0	142.4	154.2	151.6	147.3	151.0	146.71	27 "
156.6	157.6	152.6	155.6	162.0	164.8	159.3	162.0	158.81	8 June.
131.24	132.46	130.21	131.20	139.96	141.98	136.99	139.64	135.47	16 May.

FLOWERING PHENOCHRONS—*Continued.*

QUEENS COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inlands.	High-lands.	Aver- age.	Coast.	Low Inlands.	High-lands.	Aver- age.	Annual date.	Mensual date.
103.2	106.2	104.7	112.7	.....	113.8	113.2	108.97	19 April.
124.2	121.4	122.8	131.5	.....	127.4	129.4	126.12	7 May.
128.6	120.4	124.5	135.9	.....	125.8	130.8	127.67	8 "
125.5	123.7	124.6	134.4	.....	134.1	134.2	129.42	10 "
125.9	123.3	124.6	138.4	.....	134.0	136.2	130.40	11 "
140.7	138.4	139.5	147.4	.....	145.5	146.4	143.00	23 "
149.9	148.3	149.1	158.9	.....	157.9	158.4	153.75	3 June.
136.2	133.0	134.6	145.2	.....	137.2	141.2	137.90	18 May.
146.9	144.2	145.5	152.5	.....	151.1	151.8	148.67	29 "
157.0	152.6	154.8	164.2	.....	157.0	160.6	157.70	7 June.
133.81	131.15	132.48	142.11	.....	138.38	140.24	136.36	17 May.

ANNAPOLIS COUNTY, 1899.

.....	99.9	107.7	103.8	.....	110.1	117.1	113.6	198.70	19 April.
.....	124.7	126.0	125.3	.....	132.2	133.1	132.6	129.00	9 May.
.....	129.3	123.7	126.5	.....	134.0	128.4	131.2	128.85	9 "
.....	125.3	128.8	127.0	.....	133.6	135.1	134.3	130.70	11 "
.....	122.2	123.5	122.8	.....	130.7	133.5	132.1	127.47	8 "
.....	137.8	140.7	139.2	.....	143.6	146.9	145.2	142.25	23 "
.....	145.9	147.5	146.7	.....	155.1	156.3	155.7	151.20	1 June.
.....	133.4	136.0	134.7	.....	137.5	141.2	139.3	137.02	18 May.
.....	139.9	145.7	142.8	.....	148.3	152.3	150.3	146.55	27 "
.....	152.3	153.7	153.0	.....	159.1	159.4	159.2	156.12	6 June.
.....	131.07	133.33	132.20	.....	138.42	140.33	139.37	135.78	16 May.

LUNENBURG COUNTY, 1899.

102.4	104.6	105.3	104.1	111.1	114.2	114.7	113.3	108.71	19 April.
123.5	123.9	122.8	123.4	130.4	129.9	129.6	129.9	126.68	7 May.
123.6	120.2	122.0	121.9	129.7	129.4	127.5	128.8	125.40	6 "
126.2	128.3	127.0	127.1	131.3	137.2	134.0	134.1	130.66	11 "
126.0	125.3	122.7	124.6	131.6	134.1	130.2	131.9	128.31	9 "
139.1	137.2	139.9	38.7	144.2	143.2	146.5	144.6	141.68	22 "
150.5	149.7	148.9	149.7	157.6	156.6	155.0	156.4	153.05	3 June.
142.0	130.5	132.0	134.8	148.6	139.4	138.2	142.0	138.45	19 May.
144.3	145.8	144.6	144.9	155.0	152.3	152.3	153.2	149.05	30 "
158.5	154.5	153.0	155.3	164.5	159.8	156.7	160.3	157.83	7 June.
133.61	132.00	131.82	132.47	140.40	139.61	138.47	139.49	135.98	16 May.

FLOWERING PHENOCHRONS — *Continued.*

KINGS COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inlands.	High-lands.	Aver-age.	Coast.	Low Inlands.	High-lands.	Aver-age.	Annual date.	Mensual date.
.....	103.8	109.9	106.8	.....	114.8	118.6	116.7	111.77	22 April.
.....	120.7	125.8	123.2	.....	126.7	134.4	130.5	126.90	7 May.
.....	124.1	125.6	124.8	.....	132.3	133.0	132.6	128.75	9 "
.....	123.6	127.5	125.5	.....	133.6	135.8	134.7	130.12	11 "
.....	122.5	123.5	123.0	.....	133.5	131.7	132.6	127.80	8 "
.....	142.0	141.5	141.7	.....	150.2	146.3	148.2	145.00	25 "
.....	140.2	152.7	146.4	.....	153.8	157.9	155.8	151.15	1 June.
.....	136.2	134.7	135.4	.....	144.0	140.7	142.3	138.90	19 May.
.....	141.6	145.8	143.7	.....	152.6	152.4	152.5	148.10	29 "
.....	152.9	154.6	153.7	.....	159.1	161.3	160.2	156.97	6 June.
.....	130.76	134.16	132.46	.....	140.06	141.21	140.63	136.54	17 May.

HANTS COUNTY, 1899.

.....	103.8	109.3	106.5	.....	114.9	119.1	117.0	111.77	22 April.
.....	123.8	127.8	125.8	.....	129.4	134.8	132.1	128.95	9 May.
.....	126.6	126.9	126.7	.....	131.0	131.8	131.4	129.07	10 "
.....	125.2	129.6	127.4	.....	134.3	136.7	135.5	131.45	12 "
.....	123.2	126.6	124.9	.....	134.7	132.7	133.7	129.30	10 "
.....	138.6	146.2	142.4	.....	147.2	151.3	149.2	145.82	26 "
.....	141.3	153.3	147.3	.....	154.6	159.7	157.1	152.22	2 June.
.....	135.6	144.0	139.8	.....	142.6	149.5	146.0	142.92	23 May.
.....	144.7	150.8	147.7	.....	151.1	157.5	154.3	151.02	1 June.
.....	153.1	156.9	155.0	.....	160.6	163.7	162.1	158.57	8 "
.....	131.59	137.14	134.36	.....	140.04	143.68	141.86	138.11	19 May.

HALIFAX COUNTY, 1899.

104.6	105.9	108.2	106.2	119.2	114.9	118.8	117.6	111.93	22 April.
123.3	123.9	128.7	125.3	132.2	130.1	136.7	133.0	129.15	10 May.
124.6	126.3	122.7	124.5	132.7	133.9	133.0	133.2	128.86	9 "
126.3	127.5	130.1	127.9	135.9	134.4	138.6	136.3	132.13	13 "
126.9	124.0	125.8	125.5	137.1	135.3	135.5	135.9	130.76	11 "
144.1	144.1	142.6	143.6	152.9	150.1	147.3	150.1	146.85	27 "
151.8	149.6	150.0	150.4	161.5	157.2	161.0	159.9	155.18	5 June.
143.5	138.1	138.1	139.9	150.7	145.5	145.6	147.2	143.58	24 May.
154.5	148.3	151.1	151.3	164.1	156.8	157.5	159.4	155.38	5 June.
167.7	158.0	156.9	160.8	175.6	164.6	162.7	167.6	164.25	14 "
136.73	134.57	135.42	135.57	146.19	142.28	143.67	144.04	139.81	20 May.

FLOWERING PHENOCHRONS — *Continued.*

GUYSBORO COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inland.	High-lands.	Average.	Coast.	Low Inland.	High-lands.	Average.	Annual date.	Mensual date.
.....	113.8	.....	.....	.....	122.4	118.10	29 April.
.....	129.7	.....	.....	.....	135.2	132.45	13 May.
.....	123.7	.....	.....	.....	131.3	127.50	8 "
.....	135.7	.....	.....	.....	141.8	138.75	19 "
.....	132.9	.....	.....	.....	144.4	138.65	19 "
.....	148.6	.....	.....	.....	153.2	150.90	31 "
.....	159.7	.....	.....	.....	165.0	162.35	12 June.
.....	145.4	.....	.....	.....	150.8	148.10	29 May.
.....	156.5	.....	.....	.....	162.3	159.40	9 June.
.....	164.7	.....	.....	.....	169.0	166.85	16 "
.....	141.07	.....	.....	.....	147.54	144.30	25 May.

CUMBERLAND COUNTY, 1899.

116.7	111.9	110.7	113.1	123.5	121.7	118.5	121.2	117.16	28 April.
124.8	127.3	127.5	126.5	131.2	136.0	134.4	133.8	130.20	11 May.
127.4	126.8	123.1	125.7	134.6	132.7	130.9	132.7	129.25	10 "
131.4	130.2	128.8	130.1	137.6	139.7	136.0	137.7	133.95	14 "
126.8	129.0	123.7	126.5	134.3	141.3	134.7	136.7	131.63	12 "
145.9	141.1	140.4	142.4	151.2	146.9	146.4	148.1	145.31	26 "
154.7	149.1	150.3	151.3	160.3	159.5	155.8	158.5	154.95	4 June.
141.0	137.4	135.5	137.9	147.1	145.3	142.7	145.0	141.50	22 May.
152.4	149.3	149.5	150.4	158.6	154.3	155.7	156.2	153.30	3 June.
156.5	155.2	155.5	155.7	162.6	161.5	161.2	161.7	158.75	8 "
137.76	135.73	134.50	135.99	144.10	143.89	141.63	143.20	139.60	20 May.

COLCHESTER COUNTY, 1899.

106.1	112.2	118.9	112.4	118.1	117.6	125.4	120.3	116.38	27 April.
124.4	126.3	127.3	126.0	132.9	132.6	134.2	133.2	129.61	10 May.
129.5	127.9	128.9	128.7	135.3	132.5	134.6	134.1	131.45	12 "
128.4	129.7	128.9	129.0	137.2	136.3	136.6	136.7	132.85	13 "
126.8	126.5	126.0	126.4	134.7	136.2	135.0	135.3	130.86	11 "
141.3	140.3	147.4	143.0	147.3	147.8	152.4	149.1	146.08	27 "
149.3	148.6	149.5	149.1	157.5	156.7	156.1	156.7	152.95	2 June.
141.2	138.4	141.2	140.2	147.1	143.7	148.7	146.5	143.38	24 May.
148.1	146.5	152.0	148.8	155.5	154.6	158.5	156.2	152.53	2 June.
156.5	157.4	160.8	158.2	163.4	162.3	166.8	164.1	161.20	11 "
135.16	135.38	138.09	136.21	142.90	142.03	144.83	143.25	139.73	20 May.

FLOWERING PHENOCHRONS — *Continued.*

PICTOU COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inland.	High-lands.	Aver-age.	Coast.	Low Inlands.	High-lands.	Aver-age.	Annual date.	Mensual date.
107.4	111.8	112.2	110.4	118.0	122.5	119.2	119.9	115.18	26 April.
126.4	127.1	127.1	126.8	134.4	134.8	134.8	134.6	130.76	11 May.
126.7	123.3	126.2	125.4	133.0	130.1	131.9	131.6	128.53	9 "
127.3	128.6	130.4	128.7	134.5	135.5	137.2	135.7	132.25	13 "
128.8	126.2	126.7	127.2	135.8	136.8	137.2	136.6	131.91	12 "
148.5	144.6	145.9	146.3	152.8	149.7	151.0	151.1	148.75	29 "
148.8	148.7	150.0	149.1	155.7	155.9	156.4	156.0	152.58	2 June.
142.0	141.3	140.9	141.4	147.4	145.4	145.3	146.0	143.71	24 May.
150.9	146.7	149.4	149.0	156.1	153.5	156.3	155.3	152.15	2 June.
156.1	156.2	157.2	156.5	161.3	160.9	162.7	161.6	159.06	9 "
136.29	135.45	136.60	136.11	142.90	142.51	143.20	142.87	139.49	20 May.

ANTIGONISH COUNTY, 1899.

....	....	....	117.4	....	....	....	125.9	121.65	2 May.
....	....	....	127.6	....	....	....	134.6	131.10	12 "
....	....	....	132.8	....	....	....	136.6	134.70	15 "
....	....	....	130.1	....	....	....	136.8	133.45	14 "
....	....	....	128.2	....	....	....	139.9	134.05	15 "
....	....	....	146.9	....	....	....	153.4	150.15	31 "
....	....	....	153.8	....	....	....	161.0	157.40	7 June.
....	....	....	145.4	....	....	....	151.2	148.30	29 May.
....	....	....	152.9	....	....	....	158.1	155.50	5 June.
....	....	....	160.4	....	....	....	165.8	163.10	13 "
....	....	....	139.55	....	....	....	146.33	142.94	23 May.

RICHMOND COUNTY 1899.

....	....	....	110.7	....	....	....	121.5	116.10	27 April.
....	....	....	129.9	....	....	....	136.5	133.20	14 May.
....	....	....	138.2	....	....	....	145.9	142.05	23 "
....	....	....	131.6	....	....	....	140.6	136.10	17 "
....	....	....	132.0	....	....	....	140.4	136.20	17 "
....	....	....	154.0	....	....	....	159.1	156.55	6 June.
....	....	....	159.2	....	....	....	166.4	162.80	12 "
....	....	....	146.9	....	....	....	152.4	149.65	30 May.
....	....	....	160.3	....	....	....	166.9	163.60	13 June.
....	....	....	167.8	....	....	....	172.2	170.00	20 "
....	....	....	143.06	....	....	....	150.19	146.62	27 May.

FLOWERING PHENOCHRONS — *Continued.*

CAPE BRETON COUNTY, 1899.

First Seen.				Becoming Common.				General Phenochrons.	
Coast.	Low Inlands.	High-lands.	Aver- age.	Coast.	Low Inlands.	High-lands.	Aver- age.	Annual date.	Mensual date.
.....	111.8	.....	.....	.....	120.8	116.30	27 April.
.....	132.0	.....	.....	.....	137.9	134.95	15 May.
.....	128.0	.....	.....	.....	134.5	131.25	12 "
.....	132.2	.....	.....	.....	139.4	135.80	16 "
.....	127.7	.....	.....	.....	138.7	133.20	14 "
.....	150.6	.....	.....	.....	156.3	153.45	3 June.
.....	149.2	.....	.....	.....	160.7	154.95	4 "
.....	147.2	.....	.....	.....	152.9	150.05	31 May.
.....	156.6	.....	.....	.....	163.4	160.00	10 June.
.....	164.9	.....	.....	.....	170.3	167.60	17 "
.....	140.2	.....	.....	.....	147.49	143.75	24 May.

INVERNESS COUNTY, 1899.

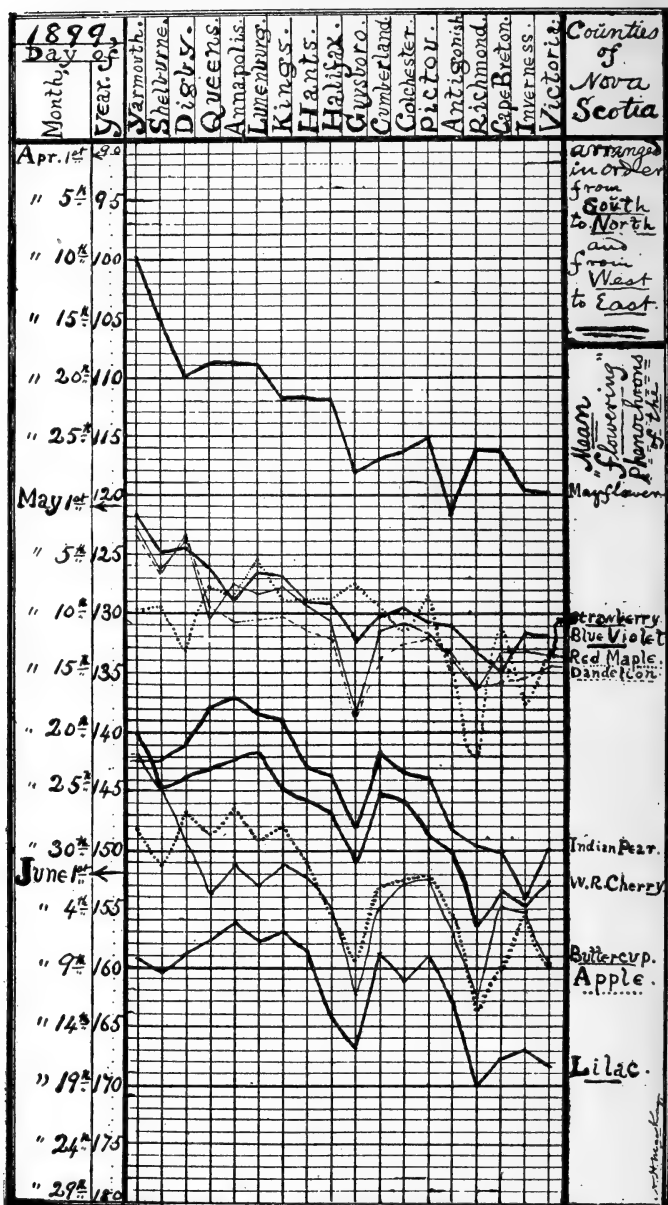
.....	.....	.....	116.5	.....	.....	.....	122.8	119.65	30 April.
.....	.....	.....	128.1	.....	.....	.....	135.3	131.70	12 May.
.....	.....	.....	134.1	.....	.....	.....	141.2	137.65	18 "
.....	.....	.....	131.9	.....	.....	.....	138.9	135.40	16 "
.....	.....	.....	129.7	.....	.....	.....	136.6	133.15	14 "
.....	.....	.....	151.9	.....	.....	.....	157.7	154.80	4 June.
.....	.....	.....	151.2	.....	.....	.....	159.3	155.25	5 "
.....	.....	.....	148.7	.....	.....	.....	159.6	154.15	4 "
.....	.....	.....	152.9	.....	.....	.....	158.5	155.70	5 "
.....	.....	.....	163.8	.....	.....	.....	170.1	166.95	16 "
.....	.....	.....	140.88	.....	.....	.....	148.00	144.44	25 May.

VICTORIA COUNTY, 1899.

.....	.....	.....	117.2	.....	.....	.....	122.3	119.75	30 April.
.....	.....	.....	129.9	.....	.....	.....	133.6	131.75	12 May.
.....	.....	.....	130.3	.....	.....	.....	136.8	133.55	14 "
.....	.....	.....	131.7	.....	.....	.....	137.3	134.50	15 "
.....	.....	.....	127.9	.....	.....	.....	135.5	131.70	12 "
.....	.....	.....	149.8	.....	.....	.....	155.2	152.50	2 June.
.....	.....	.....	155.8	.....	.....	.....	163.5	159.65	9 "
.....	.....	.....	147.2	.....	.....	.....	152.7	149.95	30 May.
.....	.....	.....	157.1	.....	.....	.....	162.8	159.95	9 June.
.....	.....	.....	164.7	.....	.....	.....	171.8	168.25	18 "
.....	.....	.....	141.16	.....	.....	.....	147.15	144.15	25 May.

PHENOCHRON CURVES OF FLOWERING.

(Mean of "first seen" and "becoming common").



Observations of Botanical Club of Canada.

In order to keep unbroken the series of observations made by the Botanical Club of Canada, in the Transactions of the Institute, especially as they have not yet become too voluminous, the following tabular summation of them for 1899 is given. The *seven* stations in the other provinces of the Dominion show observations which will be interesting in comparison with those made in Nova Scotia.

Phenological Stations and Observers of the Botanical Club of Canada, 1899.

St. Stephen, N. B.—J. Vroom, Esq.
 Yarmouth, N. S.—S. A. Starratt, Esq.; Seymour Critcher, Esq.
 Berwick, N. S.—Miss Ida A. Parker.
 Halifax, N. S.—Harry Piers, Esq.
 Musquodoboit Harbour, N. S.—Rev. James Rosborough.
 New Glasgow, N. S.—Miss Maria Cavanagh.
 Wallace, N. S.—Miss Mary E. Charman.
 Charlottetown, P. E. I.—John McSwain, Esq.
 Beatrice, Muskoka, Ontario.—Miss Alice Hollingworth.
 Pheasant Forks, Assiniboia.—Thomas R. Donnelly, Esq.
 Olds, Alberta.—T. N. Willing, Esq.
 Willoughby, Saskatchewan.—Rev. C. W. Bryden.
 Vancouver, B. C.—J. K. Henry, Esq., B. A.

Explanation of Annotations over the Date Figures in the following Table :

*—"When becoming common."	s — <i>Ranunculus rhomboideus</i> .
b— <i>Rubus spectabilis</i> (flowering).	t — <i>Fragaria Chilensis</i> .
c— " " (fruiting).	u — <i>Pronus emarginata</i> .
f— <i>Rubus occidentalis</i> .	v — <i>Tridium ovatum</i> .
k— <i>Turdus propinqua</i> .	w — <i>Trientalis Europaea</i> .
o— <i>Sturnella neglecta</i> .	x — <i>Amelanchier alnifolia</i> .
q— <i>Chordeiles Henryei</i> .	y — <i>Rosa Nutkana</i> .

PHENOLOGICAL OBSERVATIONS, CANADA, 1899.

[illegible]

PHENOLOGICAL OBSERVATIONS, CANADA, 1899.

[illegible]

PHENOLOGICAL OBSERVATIONS, CANADA, 1899.

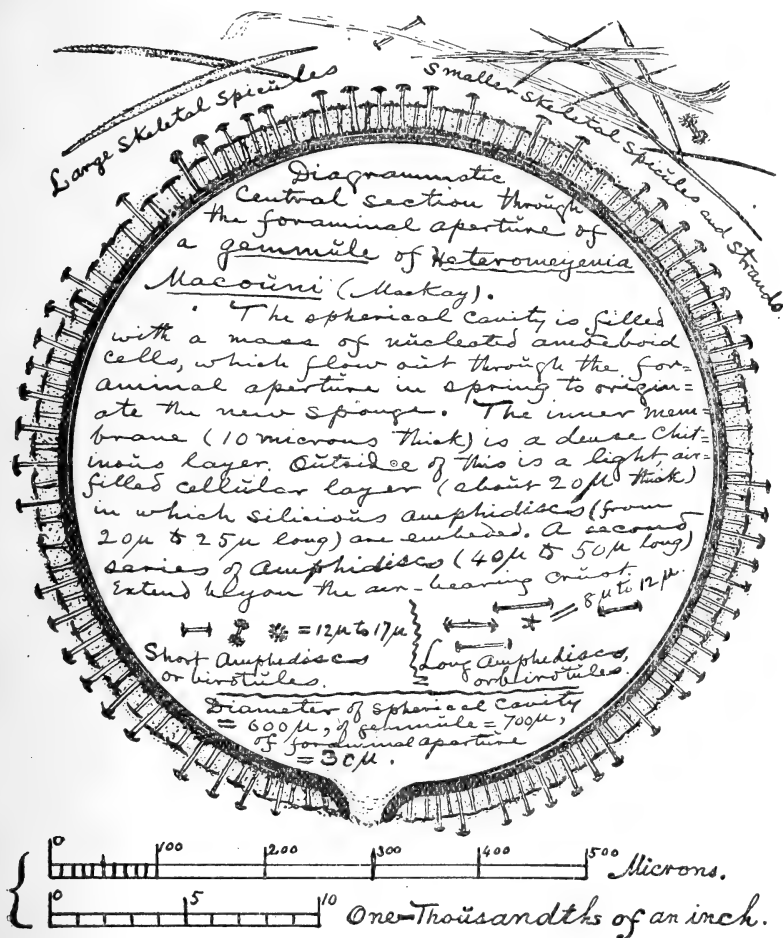
Number.	Day of the year 1899, corresponding to the last day of each month. Jan. 31 July.....212 Feb. 59 Aug.....242 March... 90 Sept.....273 April... 120 Oct .....304 May ... 131 Nov .....334 June... 181 Dec .....365 (First flowering or fruiting of plants and first appearance of migratory animals, etc.)													
		St. Stephen, N. B.	Yarmouth, N. S.	Berwick, N. S.	Halifax, N. S.	Musquodoboit, N. S.	New Glasgow, N. S.	Wallace, N. S.	Charlottetown, P. E. I.	Beatrice, Muskoka, Ont.	Pheasant Forks, Man.	Olds, Alberta.	Willoughby, Sask.	Vancouver, B. C.
77a	First autumn frost, hoar.	227	...	...	258	...	258	...	251	...	254	221	221	...
77b	“ “ hard..	...	...	...	307	...	...	...	...	...	...	...	...	...
78a	First snow to fly in air....	276	...	...	...	...	...	277	315	...	...	...	...	...
78b	“ whiten ground	294	...	...	316	...	307	294	317	...	...	...	...	...
79a	Closing of Lakes.....	...	...	...	...	...	...	319	370	...	...	...	...	...
79b	“ Rivers.....	...	...	...	...	...	341	...	...	...	...	...	...	...
80	Thunderstorms—dates....	64	64	64	...	...	64	5	64	...	...	...	...	...
		...	78	...	...	...	...	64	...	104	...	108	...	...
		122	122	...	...	...	...	121	...	120	126	...	...	...
		146	...	...	...	...	...	128	...	148	...	142	...	...
		156	156	...	...	...	...	164	...	149	...	...	...	...
		157	...	157	157	...	...	...	165	151	...	162	...	...
		165	...	...	...	...	...	...	...	155	...	169	...	...
		170	166	...	...	...	166	167	...	156	...	...	...	...
		171	...	...	...	...	...	...	...	157	172	188	...	...
		172	...	172	...	...	...	172	...	163	173	...	...	...
		176	176	...	...	...	...	174	...	165	175	200	...	...
		177	...	...	...	...	177	176	176	174	177	219	...	...
		185	..	...	...	...	...	181	177	184	178	...	...	...
		187	...	...	...	...	...	...	186	198	197	220	...	...
		194	...	...	...	...	194	194	194	214	204	221	...	...
		202	...	...	...	...	195	202	195	224	210	...	...	...
		208	...	...	...	...	...	...	200	233	212	236	...	...
		210	...	...	...	...	...	225	201	...	218	255	...	...
		...	...	216	...	...	...	...	202	...	221	...	...	...
		246	...	...	...	...	246	246	220	...	229	259	...	...
		...	...	...	316	...	247	273	226	260	231	...	...	...

PHENOLOGICAL OBSERVATIONS, CANADA, 1899

Number.	Day of the year 1899, corresponding to the last day of the month. Jan. 31 July.....212 Feb. 59 Aug. ....243 March .. 90 Sept ....273 April .. 120 Oct. ....304 May.....151 Nov ....334 June... 181 Dec.....365 (First flowering or fruiting of plants and first appearance of migratory animals, etc)													
		St. Stephen, N. B.	Yarmouth, N. S.	Berwick, N. S.	Halifax, N. S	Musquodoboit, N. S.	New Glasgow, N. S.	Wallace, N. S.	Charlottetown, P. E. I.	Beatrice, Muskoka, Ont.	Pheasant Forks, Man.	Olds, Alberta.	Willoughby, Sask.	Vancouver, B. C.
80	Thunderstorms—dates....								228	287				
									246	296				
									257					
81a	Wild ducks migrating, N.			86							110	99		
81b	“ “ S.													
82a	“ geese “ N.	100	94	78	81				90		110	100		
82b	“ “ S.		347						246	291		286		
83	Melospiza fasciata, North.	105	92	94	94				98		<i>k</i>	<i>k</i>	<i>k</i>	
84	Turdus migratorius, “	102	80	88	97		100		96		116	97	116	
85	Junco hiemalis, “		102	81	99				112					
86	Actitis macularia, “													
87	Sturnella magna “										<i>o</i> 106			
88	Ceryle Alcyon. “		102											
89	Dendroeca coronata, “		149		144									
90	D. æstiva, “				?		146							
91	Zonotrichia alba, “	120							134					
92	Trochilus colubris, “	143	128	135			144							
93	Tyrannus Carolinen , “			145										
94	Dolychonyx oryzivor, “													
95	Spinis tristis, “	144												
96	Setophaga ruticilla, “				146									
97	Ampelis cedrorum, “													
98	Chordeiles Viginian., “		151		149				156		<i>q</i> 148			
99	First piping of frogs	115	166	97	112		144		117	107	115	108	110	
100	First appearance, snakes.		109							123	127			

XIV.—A FRESH WATER SPONGE FROM SABLE ISLAND.—BY A.
H. MACKEY, LL. D., *Halifax*.

(Read 9th April, 1900.)



This sponge was collected in considerable abundance on the 18th of August, 1899, by Professor John Macoun, Botanist of

the Geological Survey of Canada, in the fresh water pond found in the centre of that great sand-shoal in the Atlantic Ocean, well known as Sable Island, nearly one hundred miles from Nova Scotia, the nearest part of the continent. It was growing around the submerged portion of the slender stems of *Myriophyllum tenellum*, Bigelow, in green, compact, lobular masses, showing, where broken, numerous orange yellow gemmules.

It appears to approach most nearly to the following fresh water sponges described by Potts: *Heteromeyenia ryderi*, v. *baleni*, found from Florida to New Jersey, in its spiculation; and *Heteromeyenia ryderi* v. *walshii*, from Gilder Pond, Massachusetts, in the fasciculation of its skeleton spicules.

General form: Encrusting the submerged stems of *Myriophyllum tenellum*, (which in the specimens examined are about 2 mm. thick), in a smooth, compact, green, lobular mass extending to a gross diameter of about one centimeter, and to a height or length along the stem of about 5 or 6 centimeters in some cases, the lobes suggesting an abortive attempt at branching; pores and osteoles very minute; gemmules very abundant, appearing wherever the central mass is broken.

Gemmules: Light orange in color, spherical, varying from 500 to 800 microns in diameter, but generally between 600 to 700 microns; foraminal aperture from 30 to 70 microns in diameter, not produced into a tube beyond the crust; dense inner (chitinous) coat of gemmule nearly 10 microns thick, surrounded by the light cellular crust (in which the short siliceous birotules or amphidisks are vertically embedded) to a depth of about 25 microns; both short and long birotules or amphidisks with one disk or rotule resting on the chitinous coat, their shafts radially directed, packed as closely as their disks allow, the long birotules being fewer with the distal rotules extending beyond the crust, their few slightly incurved rays somewhat adapted for attaching the gemmule to any finely fibrous environment.

Short birotules: From 18 to 26 microns in length, generally from 20 to 24, with a smooth uniform shaft.

ranging from 1.5 to 2 microns thick ; the rotules being plane disks less than 2 microns thick from the point where the shaft begins to swell into them, and from 10 to 16 microns in diameter, commonly near 12 microns, laciniately blunt-lobed around their margins, the shaft occasionally extending 1 micron beyond the disks, making the exterior of the rotule slightly umbonate.

Long birotules: From 35 to 50 microns, commonly from 40 to 45, with usually a smooth, uniform shaft about 2 microns thick ; the rotules generally of 3, to 4 or 5 rays which are slightly incurved, the rotule ranging from 8 to 14 microns in diameter, commonly from 10 to 11 microns.

Larger skeleton spicules: Slightly curved, microspined or rough, tapering gradually from the middle, then more rapidly towards the ends ; ranging from 150 to 260 microns in length, commonly from 180 to 220 ; and from 3.5 to 5 microns in breadth at the thickest part.

Intermediate skeleton spicules: Generally smooth, and from 2 to 3 microns thick, and from 150 to 200 microns in length, numerous and generally fascicled into strands which are often connected transversely by the larger spicules.

Smaller strand spicules and filament strands: Finer strands than those referred to above, appearing as if made up of continuous filaments instead of spicules ; strands commonly from 10 to 15 microns across, made up of about 20 filaments or more, each about one micron thick, where broken across appearing as if they were flexible to some extent, the ends of the filaments showing a more or less distinct curvature. Under the microscope they appear identical with the more slender spicules with the exception that they appear to be continuous in the strand. Examined with polarized light they are visible in the dark field, as are also, more or less, the strands made up of the intermediate spicules while the spicules are cemented together, suggesting a peculiar colloidal siliceous or a spongin cement. When heated with nitric acid these filaments appear first to separate and break into pieces, then partly at least to disappear. At the earliest opportunity I purpose to examine the nature of these

strands and their relationship to the other portions of the skeleton; but this crude provisional treatment of them suggested that the filaments might be spongin fibres partly silicified, or nascent siliceous spicules.

The two classes of birotules arming the gemmule put the sponge into Potts's genus *Heteromeyenia*. I therefore propose the name *Heteromeyenia macouni*, in allusion to the distinguished naturalist who discovered it. It is possible that a comparison of the sponge with the two varieties referred to first above as approximating to this species may reduce it to *Heteromeyenia ryderi* v. *macouni*; but from the descriptions published it appears to be specifically distinct.

The sponge is especially interesting on account of its habitat in the only fresh water pond of a sand island in the Atlantic Ocean nearly 100 miles from the continent. The island is about 20 miles long at present and about one mile broad. It has been described as consisting of "two parallel ridges of loose grey sand, in a bow or crescent shape, with the inner side to the north. In the valley between these is a lake, now not more than eight miles long, formerly nearly twice that length."* This is the pond in which *Heteromeyenia macouni* has been growing in abundance.

* Sable Island: Its History and Phenomena, by Rev. George Patterson, D. D., in Transactions of the Royal Society of Canada, Section II., 1894, (3).

APPENDIX.—II.

LIST OF MEMBERS, 1899-1900.

ORDINARY MEMBERS.

	<i>Date of Admission.</i>
Allison, Augustus, Halifax.....	Feb. 15, 1869
Austen, James H., Crown Lands Department, Halifax...	Jan. 2, 1894
Bayer, Rufus, Halifax.....	March 4, 1890
Bishop, Watson L., Dartmouth, N. S.....	Jan. 6, 1890
Bliss, Donald M., Boston, U. S. A.....	Jan. 31, 1890
Bowman, Maynard, B. A., Public Analyst, Halifax.....	March 13, 1884
Brown, R. Balfour, Yarmouth, N. S.....	Jan. 10, 1891
Butler, Professor Wm. R., C. E., Royal Military College, Kingston, Ont.	Nov. 27, 1889
Campbell, Donald A., M. D., Halifax.....	Jan. 31, 1890
Campbell, George Murray, M. D., Halifax.....	Nov. 10, 1884
Clements, E. F., Yarmouth, N. S.....	Jan. 10, 1891
Cowie, Andrew J., M. D., L. R. C. P. E., Halifax.....	Jan. 27, 1893
DeWolfe, James R., M. D., L. R. C. S. E., Halifax.....	Oct. 26, 1865
Dick, Alexander, M. E., Halifax.....	Nov. 29, 1894
Doane, F. W. W., City Engineer, Halifax.....	Nov. 3, 1886
Donkin, Hiram, C. E., Point Tupper, Cape Breton.....	Nov. 30, 1892
Egan, Thomas J., Halifax.....	Jan. 6, 1890
Elliott, Miss Bertha, Dartmouth, N. S.....	March 4, 1895
Fearon, James, Principal Deaf and Dumb Institution, Halifax.....	May 8, 1894
Finn, Wm. D., M. D., Halifax.....	Oct. 29, 1894
Faville, E. E., President, National Farm School, Doylestown, Pa.....	Nov. 29, 1894
Forbes, John, Halifax.....	March 14, 1883
Foster, James G., Judge of Probate, Dartmouth, N. S.....	March 14, 1883
Fraser, C. F., Principal, School for the Blind, Halifax.....	March 31, 1890
Fraser, Rev. W. M., B. A., B. Sc., Halifax.....	Nov. 29, 1894
Gates, Herbert E., Architect, Dartmouth, N. S.....	April 5, 1899
Gilpin, Edwin, M. A., LL. D., F. R. S. C., Inspector of Mines, Halifax.....	April 11, 1873
Greer, T. A., M. D., Colborne, Ontario.....	April 7, 1893
Hall, Charles Frederick.....	Dec. 31, 1894
Hare, Alfred A.....	Dec. 12, 1881
Harris, Herbert, Vancouver, British Columbia.....	Jan. 31, 1880
Hattie, William Harrop, M. D., Halifax.....	Nov. 12, 1892
Hendry, William A., Jr., C. E., Windsor, N. S.....	Jan. 4, 1892
Irving, G. W. T., Halifax.....	Jan. 4, 1892
Jacques, Hartley S., M. D., Halifax.....	May 8, 1894
Johnston, Henry W., C. E., Halifax.....	Dec. 31, 1894
*Keating, E. H., C. E., City Engineer, Toronto, Ontario.....	April 12, 1882
Kennedy, W. T., Principal, County Academy, Halifax.....	Nov. 27, 1889

* Life Member.

Date of Admission.

Laing, Rev. Robert, Halifax	Jan. 11, 1885
Locke, Thomas J., Halifax	Jan. 4, 1892
McColl, Roderick, C. E., Halifax	Jan. 4, 1892
Macdonald, Simon D., F. G. S., Halifax	March 14, 1881
Macdonald, W. A., C. E., Sydney, C. B.	April 5, 1899
MacGregor, Prof. James Gordon, M. A., D. Sc., F. R. S., Dalhousie College, Halifax	Jan. 11, 1877
McInnes, Hector, LL. B., Halifax	Nov. 27, 1889
*McKay, Alexander, Supervisor of Schools, Halifax	Feb. 5, 1872
*MacKay, Alex. Howard, B. A., B. Sc., LL. D., F. R. S. C., Superintendent of Education, Halifax	Oct. 11, 1885
MacKay, Prof. Ebenezer, Ph. D., Dalhousie College, Halifax	Nov. 27, 1889
McKerron, William, Halifax	Nov. 30, 1891
MacNab, William, Halifax	Jan. 31, 1890
Marshall, G. R., Principal, Richmond School, Halifax	April 4, 1894
Mason, F. H., F. C. S., Halifax	Dec. 31, 1894
Morrow, Arthur, M. D., Sand Coulee, Montana, U. S. A	Nov. 27, 1889
Morton, S. A., M. A., County Academy, Halifax	Jan. 27, 1893
Murphy, Martin, C. E., D. Sc., Provincial Engineer, Halifax	Jan. 15, 1870
Newman, C. L., Dartmouth, N. S.	Jan. 27, 1893
O'Hearn, Peter, Principal, St. Patrick's Boys' School, Halifax	Jan. 16, 1890
*Parker, Hon. Daniel McN., M. D., M. L. C., Dartmouth, N. S.	1871
Pearson, B. F., Barrister, Halifax	March 31, 1890
Piers, Harry, Halifax	Nov. 2, 1888
*Poole, Henry S., F. G. S., F. R. S. C., Stellarton, N. S.	Nov. 11, 1872
Read, Herbert H., M. D., L. R. C. S., Halifax	Nov. 27, 1889
*Robb, D. W., M. E., Amherst, N. S.	March 4, 1890
Rutherford, John, M. E., Stellarton, N. S.	Jan. 8, 1865
Shine, Michael, Halifax	Dec. 3, 1891
Silver, Arthur P., Halifax	Dec. 12, 1887
Silver, William C., Halifax	May 7, 1864
Smith, Capt. Wm Henry, R. N. R., F. R. G. S., Halifax	Nov. 27, 1889
Stewart, John, M. B., C. M., Halifax	Jan. 12, 1885
Tremaine Harris S., Halifax	Jan. 2, 1894
Weatherbe, Hon. Mr. Justice, Halifax	March 28, 1895
Wheaton, L. H., Chief Engineer, Coast Railway Co., Yarmouth, N. S.	Nov. 29, 1894
Willis, C. E., M. E., Halifax	Nov. 29, 1894
Wilson, Robert J., Secretary, School Board, Halifax	May 3, 1889
*Yorston, W. G., C. E., Truro, N. S.	Nov. 12, 1892

ASSOCIATE MEMBERS.

*Caie, Robert, Yarmouth, N. S.	Jan. 31, 1890
*Cameron, A., Principal of Academy, Yarmouth, N. S.	Nov. 27, 1889
Coldwell, Professor A. E., M. A., Wolfville, N. S.	Nov. 27, 1889
DeWolfe, Melville G., Kentville, N. S.	May 2, 1895
*Dickenson, S. S., Superintendent, Commercial Cable Co., Hazelhill, Guysborough Co., N. S.	March 4, 1895
Eaton, F. H., M. A., Superintendent of Public Schools, Victoria, B. C.	Jan. 6, 1890
Edwards, Arthur M., M. D., F. L. S., Newark, N. J.	Dec. 6, 1898
Faribault, E. R., C. E., Ottawa, Ontario ..	March 6, 1888
Halliday, And., M. D., Shubenacadie, N. S.	Dec. 6, 1898
Hardman, John E., M. E., Montreal	March 4, 1890

* Life Member.

LIST OF MEMBERS.

VII

Date of Admission.

Haycock, Prof. Ernest, Acadia College, Wolfville, N. S.	May 17, 1899
Hunton, Prof. S. W., M. A., Mount Allison College, Sackville, N. B.	Jan. 6, 1890
James, C. C., M. A., Dep. Min. of Agriculture, Toronto, Ontario	Dec. 3, 1896
*Johns, Thomas W., Yarmouth, N. S.	Nov. 27, 1889
Kennedy, Prof. Geo. T., M. A., D. Sc., F. G. S., King's College, Windsor, N. S.	Nov. 9, 1882
MacIntosh, Kenneth, St. George's Channel, Richmond Co., C. B.	Jan. 4, 1892
McKenzie, W. B., C. E., Moncton, N. B.	March 31, 1882
McLeod, R. R., Brookfield, N. S.	Dec. 3, 1897
Magee, W. H., Ph. D., High School, Lunenburg, N. S.	Nov. 29, 1894
Matheson, W. G., M. E., New Glasgow, N. S.	Jan. 31, 1890
Prest, Walter H., Bedford, N. S.	Nov. 29, 1894
*Reid, Alex. P., M. D., L. R. C. S., Middleton, N. S.	Jan. 31, 1890
Rosborough, Rev. James, Musquodoboit Harbor, N. S.	Nov. 29, 1894
Russell, Lee, B. S., Normal School, Truro, N. S.	Dec. 3, 1896
Smith, Prof. H. W., B. Sc., Prov. Agricultural School, Truro, N. S.	Jan. 6, 1890

CORRESPONDING MEMBERS.

Ami, Henry M., D. Sc., F. G. S., Ottawa, Ontario	Jan. 2, 1892
Bailey, Prof. Loring Wort, Ph. D., LL. D., F. R. S. C., University of New Brunswick, Fredericton, N. B.	Jan. 6, 1890
Ball, Rev. Edward H., Tangier, N. S.	Nov. 29, 1871
Bethune, Rev. C. J. S., Port Hope, Ontario	Dec. 29, 1868
Davidson, Prof. John, Phil. D., Univ. of N. Brunswick, Fred'ton, N. B.	Dec. 12, 1898
Dobie, W. Henry, M. D., Chester, England	Nov. 3, 1897
Duns, Prof. John, LL. D., F. R. S. E., New College, Edinburgh, Scotland	Dec. 30, 1887
Ells, R. W., LL. D., F. G. S. A., F. R. S. C., Geological Survey, Ottawa, Ont.	Jan. 2, 1894
Fletcher, Jas., LL. D., F. L. S., F. R. S. C., Entomologist and Botanist, Central Exp. Farm, Ottawa, Ont.	March 2, 1897
Fletcher, Hugh, B. A., Geological Survey, Ottawa, Ontario	March 3, 1891
Ganong, Prof. Wm. F., B. A., Ph. D., Smith College, Northampton, Mass., U. S. A.	Jan. 6, 1890
Harrington, Wm. Hague, F. R. S. C., Post Office Department, Ottawa	May 5, 1896
Harvey, Rev. Moses, LL. D., F. R. S. C., St. John's, Newfoundland	Jan. 31, 1890
King, Major, R. A.	Nov. 19, 1877
Litton, Robert T., F. G. S., Melbourne, Australia	May 5, 1892
McClintock, Vice-Admiral Sir Leopold, Kt., F. R. S.	June 10, 1880
Matthew, G. F., M. A., D. Sc., F. R. S. C., St. John, N. B.	Jan. 6, 1890
Maury, Rev. Mytton, D. D., Ithaca, N. Y., U. S. A.	Nov. 30, 1891
Peter, Rev. Brother Junian, St. Joseph's Commercial College, Detroit, Mich.	Dec. 12, 1898
Pickford, Charles, Halifax	March 2, 1900
Prince, Prof. E. E., Commissioner and General Inspector of Fisheries, Ottawa, Ontario	Jan. 5, 1897
Smith, Hon. Everett, Portland, Maine, U. S. A.	March 31, 1890
Spencer, Prof. J. W., Ph. D., F. G. S., Washington, D. C., U. S. A.	Jan. 31, 1890
Waghorne, Rev. Arthur C., St. John's, Newfoundland	May 5, 1892
Weston, Thomas C., F. G. S. A., Ottawa, Ontario	May 12, 1877

* Life Member.

